

OFFICE OF  
MANNED SPACE FLIGHT

APOLLO PROGRAM

**APOLLO CSM AND LM  
ELECTRICAL INSPECTION  
CRITERIA**

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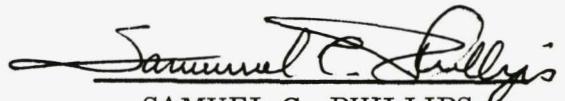
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## PREFACE

This document establishes uniform Apollo CSM and LM electrical acceptance and rejection criteria for the inspection practices used in the Apollo Program. Photographs and sketches have been used in many cases to illustrate the acceptability required for the inspection of electrical fabrication at contractors' plants and at NASA installations, both by contractor and Government inspectors.



SAMUEL C. PHILLIPS  
Major General, USAF  
Apollo Program Director

## FOREWORD

The photographs that are used within this document, in many cases, represent actual workmanship in spacecraft fabrication. Specific photographs depict a particular defect, but at the same time they may depict other practices that are both good and bad. The subject of interest for a given photograph is mentioned in the respective captions; however, the reader should study the photograph in other respects, too. In some instances, one photograph serves to illustrate material in more than one section in this document; in such cases the reader is directed to it by appropriate references in the text.

The top of any given photograph, as shown in the text, does not necessarily reflect the actual orientation of the subject matter as it exists in the Command Service Module (CSM) or Lunar Module (LM).

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## SECTION 1

### INTRODUCTION

#### 1.1 PURPOSE

The intent of this document is to establish uniform criteria to be used for inspecting the electrical fabrication and installation in the Apollo Command Service Module (CSM) and Lunar Module (LM). This document shall be the basis for contractors and their suppliers to develop detailed implementation procedures.

#### 1.2 POLICY

NASA and contractor Quality Assurance personnel are responsible for ensuring that all flight hardware complies with the workmanship requirements of this document. All inspectors shall be trained and examined, as defined in Section 3, using the contents of this document as a basis for accepting or rejecting electrical fabrication and installation in the Apollo spacecraft. Training programs of all contractor, NASA, or other Government Agency inspectors will be reviewed, approved, and monitored by MSC or its authorized representatives.

#### 1.3 SCOPE

##### 1.3.1 APPLICABILITY

The requirements established herein are applicable to all NASA organizations, Government Agencies, and contractors participating in contracts for spacecraft flight hardware in the Apollo Program. This document specifies the inspection criteria that shall be used for the following categories:

- a. Wire Bundle Fabrication and Routing.
- b. Support and Clamping of Wire
- c. Mechanical and Soldered Terminal Connections.
- d. Printed Circuit and Terminal Board Assemblies.
- e. Splices and Shield Terminations.
- f. Chafing and Clearances.
- g. Potting, Molding, and Conformal Coating.
- h. Connectors and Safety Wiring.

- i. Stowage.
- j. Tool and Equipment Control.
- k. Identification.
- l. Cleanliness.

In addition to the categories listed above, training program requirements and documentation requirements are specified herein.

#### 1.3.2 APPLICABLE DOCUMENTS

All documents that contain contractually imposed electrical fabrication or inspection criteria and/or requirements form a part of this document. It is not the intent of this document to reference all of the standards, criteria, and other specifications associated with the electrical inspection of CSM and LM. The documents listed below reflect only those that are specifically mentioned in the text of this document, but do not reflect a complete list of contractually imposed documents. Unless otherwise stated herein, the latest issue of the following documents shall apply:

- a. FED-SPEC-SS-P-821, Gold Plating
- b. FED-SPEC-O-E-760, Ethyl Alcohol
- c. FED-STD-209, Clean Room and Work Station Requirements, Controlled Environment
- d. MIL-G-4343, Grease, Pneumatic Systems
- e. MIL-O-6086, Lubricating Oil, Gear, Petroleum Base
- f. MSC-ASPO-S-5C, MSC-ASPO Soldering Specification
- g. MSC-ASPO-S-6A, MSC Supplement to NPC 200-4—June 1, 1966
- h. MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections
- i. MSC-SPEC-C-5A, Specification for Apollo Spacecraft Cleanliness
- j. MSC-SPEC-C-8, Apollo On-board Equipment Cleanliness
- k. MSC-STD-C-4, Clean Rooms and Work Stations
- l. MSFC-STD-154A, Standards for Printed Circuit Design and Construction
- m. NHB 5300.1A, Apollo R&QA Program Plan
- n. NHB 5300.2, Apollo Metrology Requirements Manual
- o. NPC 200-4, Quality Requirements for Hand Soldering of Electrical Connections

#### **1.4 GENERAL**

Quality workmanship needed for Apollo mission success requires detailed attention by all personnel, not merely by those performing or supervising fabrication and inspection operations. Each individual needs to be provided with the knowledge, skills, training, motivation, tools, and work environment required to produce quality hardware.

Within this document are presented basic requirements that shall be used in achieving the goals of the Apollo Program. "Personal preference" requirements and creation of elaborate control systems shall be eliminated and be replaced by proven practices. In establishing such practices, the major elements that are essential to the success of the Apollo Program are basically to assure that:

- a. Personnel are well trained to established criteria.
- b. The hardware is made in conformance with approved drawings and not according to personal opinions of what constitutes "good enough".
- c. Good practices are established and that effective process controls prevail.
- d. All nonconformances are noted and that these are corrected, rejected, or accepted by responsible authority.
- e. Records are kept of the nonconformances for future review.
- f. Action has been taken to prevent recurrence of nonconformances.

These and other subjects are presented in the various Sections of this document. Although these subjects deal specifically with inspection criteria, they shall be used by the contractors as a baseline to establish specific detailed workmanship requirements for the Apollo spacecraft hardware.

## SECTION 2

### DOCUMENTATION AND RECORDS

#### 2.1 GENERAL

The intent of this Section is to establish requirements for documenting and recording inspection actions as well as nonconformance dispositions and corrective actions. It is not the intent of this Section to alter drastically the contractors' or NASA's paper systems but to establish basic documentation.

The prime contractor design representative must coordinate all engineering decisions with the responsible NASA Center design group. Similarly, subcontractor design representatives must coordinate all engineering decisions with the responsible prime contractor design groups.

#### 2.2 RECORDS

The requirements for maintaining inspection and test records by contractors and Government Agencies are detailed below.

##### 2.2.1 CONTRACTOR RECORDS

The contractor shall maintain complete and legible records of all inspections and tests performed. The records shall provide objective evidence that the required inspections and tests have been performed. These records shall include inspection and test data, part or component identification, inspection or test involved, nature of defects, basic causes for rejection, and correction action taken to preclude the recurrence of the rejected condition. These data shall cover both conforming and nonconforming items and shall identify the technicians and quality personnel performing the work.

Contractor documents outlining or authorizing work shall be written in a fashion which will allow step-by-step performance by technicians and acceptance by Quality Control. Work documents for such special processes as potting, conformal coating, etc., shall contain provisions for inspection verification of readiness to

proceed at critical points in the process. For example, work documents specifying potting of wiring should contain the following points, each to be "okayed" by inspection prior to proceeding to the next step:

- a. "Okay to etch" indicating that insulation has been properly cleaned and prepared for the etching process.
- b. "Okay to prime" indicating that etching has been satisfactorily accomplished, that no more than the maximum specified time has elapsed since the etching of the wire, etc.
- c. "Okay to pot" indicating that the wiring has been satisfactorily primed; and that the potting is the proper type within its specified shelf life, has been properly mixed, and identified.
- d. "Potting is okay" indicating potting has properly cured.

Inspection checklists shall be developed and used by the contractor to assure that all installations are thoroughly inspected prior to final closeout of any space-craft area.

#### 2.2.2 NASA RECORDS

NASA actions shall be documented on NASA and/or contractor records. The records shall provide evidence that all required NASA inspections and tests have been performed. Actual numerical or observed results obtained by NASA-independent inspections and tests shall be recorded when:

- a. The results do not agree with those recorded by the contractor.
- b. Additional inspections or tests are considered necessary by NASA.

Whenever the recording of actual results is not required, records shall be stamped to indicate clearly only those characteristics actually verified, inspected, or tested by NASA. Records shall include detailed descriptions of problems and nonconformances. When a Government Agency has been delegated to perform these functions for NASA, the Agency will be responsible for complying with these requirements.

#### 2.3 DOCUMENTATION OF NONCONFORMANCE ACTIONS

Each action taken on the disposition of nonconformance is to be documented carefully. Such documentation shall be in sufficient detail to facilitate a complete analysis of the problem. The discrepant equipment and its system or next assembly

shall be adequately identified. The record shall include not only the actual results of test or inspection, but also the specification parameters which were not met.

When material is first found to depart from specified requirements, it will be properly identified as nonconforming for purposes of disposition and, where practical, shall be isolated from normal channels of fabrication and processing.

There are three basic categories of nonconformance which shall be identified in the documentation. These categories are described in the following paragraphs.

#### 2.3.1 WORKMANSHIP DEFECTS

This category includes workmanship defects such as misplaced string ties, loose or missing hardware, improper clamping, dirt, etc., which can be readily corrected without engineering dispositioning. The response to this category of nonconformance requires technician disposition and corrective action and must be approved and accepted by both contractor Quality Control and NASA Quality Control.

#### 2.3.2 MINOR REWORK TO DRAWING

This category of nonconformance includes minor rework according to drawings, removal and replacement of failed hardware, and approved standard repairs. These dispositions and corrective actions must be accepted by contractor Quality Control and NASA Quality Control.

#### 2.3.3 MRB REVIEW

This category includes all nonconformances which do not fall in previously described categories or which initially may have been "workmanship defects" or "minor rework to drawing" nonconformances that require resolution at a higher level. These nonconformances require disposition by an MRB, the membership having been constituted in accordance with the provisions as set forth in NHB 5300.1A, Apollo Reliability and Quality Assurance Program Plan, Section 9.3, "Material Review Board Membership".

##### 2.3.3.1 MRB Disposition

Following are detail considerations for three options possible through MRB action.

#### 2.3.3.1.1 "Use As Is" Disposition

Nonconforming material determined to be usable "as is" will be identified as non-conforming with the MRB number so that a re-evaluation may be made as to the effect on higher levels of assembly at later assembly, inspection, and test points.

#### 2.3.3.1.2 Repair Disposition

Nonconforming material which in the opinion of the MRB can be made acceptable by repair under existing approved processes or assembly procedures previously authorized by MRB action for the particular application will be so repaired. Where special techniques appear to offer the possibility of satisfactory repair, disposition may be delayed while the contractor develops and documents the repair technique and obtains approval of the MRB.

Repaired articles will be re-inspected by the contractor and NASA personnel to the standards established by the approved repair procedure. All paperwork related to acceptably repaired articles will be forwarded to the cognizant MRB to insure continuity of records. Unacceptably repaired articles and the related paperwork will be resubmitted to the MRB for disposition. Material which has received a repair disposition will be identified by MRB number to permit re-evaluation as to the effect of the repair on higher levels of assembly.

#### 2.3.3.1.3 Scrap Disposition

When the MRB determines that the nonconforming material cannot be accepted "as is" or satisfactorily repaired, it will be dispositioned as scrap and processed according to locally approved procedures.

### 2.4 CONTRACTING OFFICER ACTION

The contractor or NASA may request action by the contracting officer for:

- a. A repair which is so extensive or time consuming that contract cost or delivery schedule will be affected. Authority for such a repair must be obtained prior to initiation of work.

- b. A waiver of requirements for acceptance of articles containing nonconformances which could, in the judgment of qualified personnel, result in:
  - (1) Potentially hazardous or unsafe conditions for individuals using or maintaining the contractual end item into which the article is to be installed, or
  - (2) An adverse effect on reliability, durability, or performance of the contractual end item, or
  - (3) An adverse effect on interchangeability requirements, or
  - (4) An adverse effect on weight when the weight of the nonconforming article is a critical factor and when the repair adversely affects this individual weight requirement, or
  - (5) A deviation from end-item specification.

## **2.5 DOCUMENTATION OF NONCONFORMANCE ACTION SUMMARIES**

A summary of nonconformances by category and the resulting dispositions and corrective actions shall be prepared by the contractor at major program milestones specified by NASA. These summaries shall be periodically updated. The summary should also include a tabulation which shows recurring discrepancies. The purpose of this summary will be to facilitate a review of past nonconformances and to audit the actual implementation of planned corrective actions resulting from these nonconformances. A similar system shall be implemented by NASA when the contractor's inspection is not involved. For all nonconformances, such reviews and audits will determine that:

- a. Action has been taken to identify the cause.
- b. Corrective action has been taken to preclude recurrence.
- c. Follow-up measures are being taken to assure that corrective action is timely and effective.

## SECTION 3

### TRAINING AND QUALIFICATION

#### 3.1 GENERAL

All prime contractor, subcontractor, or Government personnel who perform inspection of electrical workmanship on Apollo spacecraft hardware shall be trained and tested by written examination prior to performing such inspection on:

- a. Engineering or experimental models.
- b. Prototype models.
- c. Flight equipment.

#### 3.2 ACHIEVEMENT OF QUALIFIED STATUS

Apollo qualified status will be achieved by personnel who attend and satisfactorily complete a course of instruction in the interpretation and application of the criteria set forth in this document. All such personnel shall have demonstrated their skill and proficiency by preparing or inspecting test specimens using the methods, materials, and equipment described in this document.

Only personnel who successfully pass both the written and practical training requirements to the satisfaction of the instructor examiner shall be considered qualified to perform inspection functions on Apollo hardware. Manned Spacecraft Center (MSC) will establish and periodically update training requirements for Government and contractor inspection personnel.

#### 3.3 CONTRACTORS' TRAINING PROGRAMS

Apollo spacecraft prime contractors shall establish and maintain effective training and qualification programs which are subject to review and approval by MSC. Each program shall provide for training by the contractor using methods, materials, and equipment described in applicable Apollo contract requirements. The contractor shall prepare and maintain records on all trained personnel. Guidance for establishing training programs will be furnished to prime contractors by MSC.

MSC will make arrangements for Government inspection personnel to attend the contractor's training program.

### 3.4 TRAINING PROGRAM EVALUATION

The contractor training programs shall be reviewed, approved, and monitored by MSC.

### 3.5 SPECIALIZED TRAINING

NASA and authorized contractor personnel performing fabrication, as well as, inspection of certain selected processes used on Apollo hardware may require specialized course instruction on such processes.

## SECTION 4

### WIRE BUNDLE FABRICATION AND ROUTING

#### 4.1 GENERAL

This Section establishes the inspection criteria that pertain to wire bundle fabrication and routing. Several elements of wire bundle fabrication and installation into the spacecraft such as chafing, clearances, terminal connections, connectors, potting, and conformal coating are covered elsewhere in this document. These criteria are to be used for the inspection of complete wire bundles, including routing, not only during fabrication but also during subsequent repair, rework, and testing activities. It is essential that the original quality of workmanship that precedes installation of the completed wire bundles into the spacecraft be preserved and that the wire used shall be as specified in the applicable drawings and/or specifications.

#### 4.2 CONTAMINATION

Prior to fabrication, wiring shall be cleaned and maintained in a state of cleanliness. Compressed air shall not be used for cleaning. After installation, the wiring shall be maintained in a clean condition, free of residue and foreign materials.

Certain hydrocarbon and water-based cleansing agents have been found to attack particular insulating materials. For example, Freon, trichlorethylene, and MEK attack silicone rubber and shall not be used to clean wires that have been assembled to connectors using silicone rubber insulation or potting. Approvals of all cleansing agents brought in contact with assembled hardware shall be in writing by the manufacturers of the materials comprising the assembly. Such approvals shall be made available to and be subject to review by the procuring installation or its designated representatives.

#### CAUTION

Water-glycol solutions are considered to be extremely detrimental to wiring. All water-glycol spills require Material Review Board (MRB) action.

#### 4.3 DAMAGE

Wires or cables shall not be pulled to facilitate harness installation, removal, or repair, nor to secure additional slack. Any visible evidence of damage to wire insulation or conductors is cause for rejection. (Refer to Figure 4-1.) Protection shall be provided to prevent damage to the wire, bundles, or other parts during installation and rework. In addition, the following protective measures shall be taken:

- a. Wiring and components shall be protected from damage or contamination at all times during and after installation.
- b. Protective covers shall be provided in areas adjacent to the work area to prevent wire damage while working in or on the spacecraft.
- c. During installation or rework, precautions shall be taken to prevent bends in wires or cables.

#### 4.4 PERMANENT WIRE PROTECTION

##### 4.4.1 PROTECTIVE DEVICES

A complete visual inspection shall be made of all surfaces coming into contact with wire bundles to verify that no sharp or rough edges exist. Protective devices shall be installed to provide permanent wire protection from abrasion or other damage. (Refer to Figure 4-2.) Protection shall be installed where wiring is routed across protruding or sharp edges of structures; through or across unprotected holes or cutouts; where wiring can contact protruding rivets or other fasteners (Refer to Figure 4-3.); and at any location where the danger of chafing the wires exists. Particular attention shall be given to slack wiring in this respect.

##### 4.4.2 CLEARANCES

A minimum of 1/2 inch separation between wires or bundles and fluid lines, high temperature equipment, or vehicle structures shall be maintained by clamps or other approved devices as specified in the applicable drawings. The device used shall not depend on the gas or liquid lines for support. (Refer to Figures 4-4 and 5-2.)

Wiring shall be protected from high temperature equipment such as resistors, exhaust stacks, heating ducts, and similar items.



Figure 4-1. The insulation of a wire is damaged. Also notice that the spot tie passes between wires at the lower right—a cause for rejection.

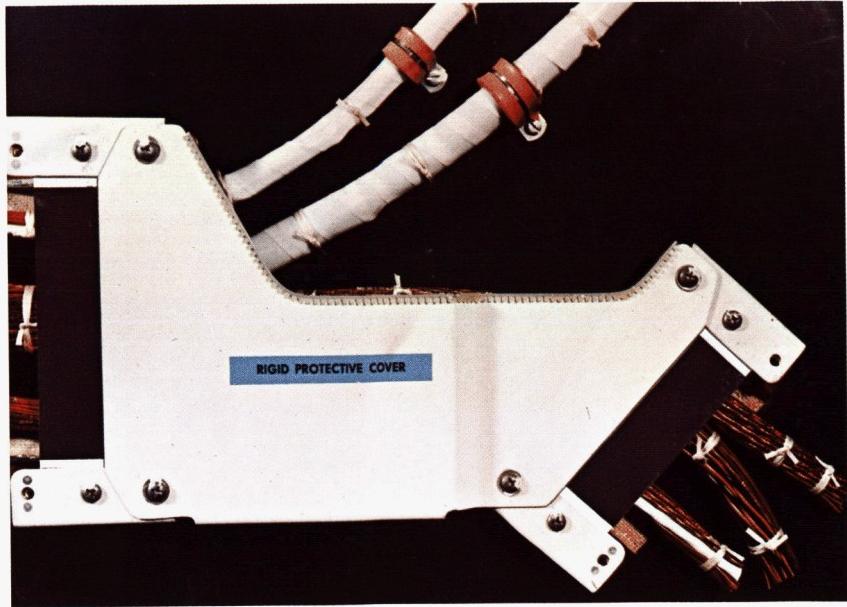


Figure 4-2. Wire bundle routing that has a rigid protective cover. Also notice neat appearance of bundle routing and clamping.

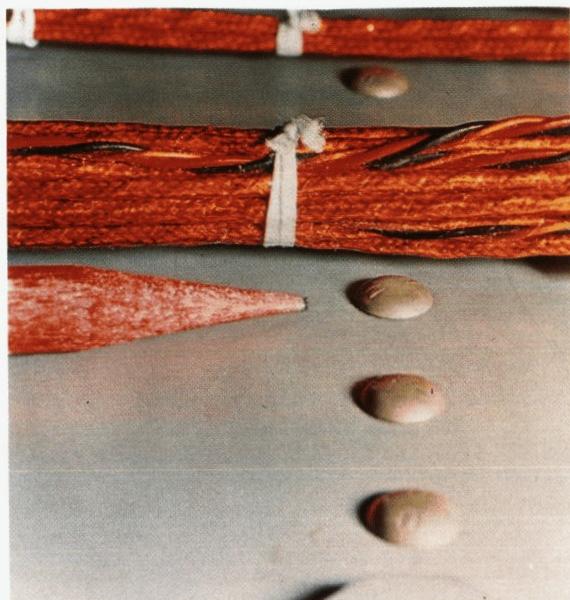


Figure 4-3. The wire bundle which is not protected could be damaged by abrasion from contact with the rivet.



Figure 4-4. Cause of rejection—three wire bundles spot tied to a rotary switch for support.

All wiring routed within six inches of oxygen, hydrogen, or propellant lines shall be sleeved or taped using approved materials according to applicable specifications or engineering drawings. A minimum physical separation of 1/2 inch from these lines shall be maintained by positive mechanical supports.

#### 4.4.3 WIRING ON OR NEAR MOVING PARTS

Wiring that is attached to assemblies where relative movement occurs or near rotating parts or hinges shall be installed and/or protected in such a manner as to prevent damage caused by movement. This deterioration includes abrasion caused by one wire rubbing against another or by twisting and bending. Wire bundles should be rerouted, or protective devices shall be installed to provide permanent wire protection from abrasion and/or other damage. (Refer to Figure 4-5.)

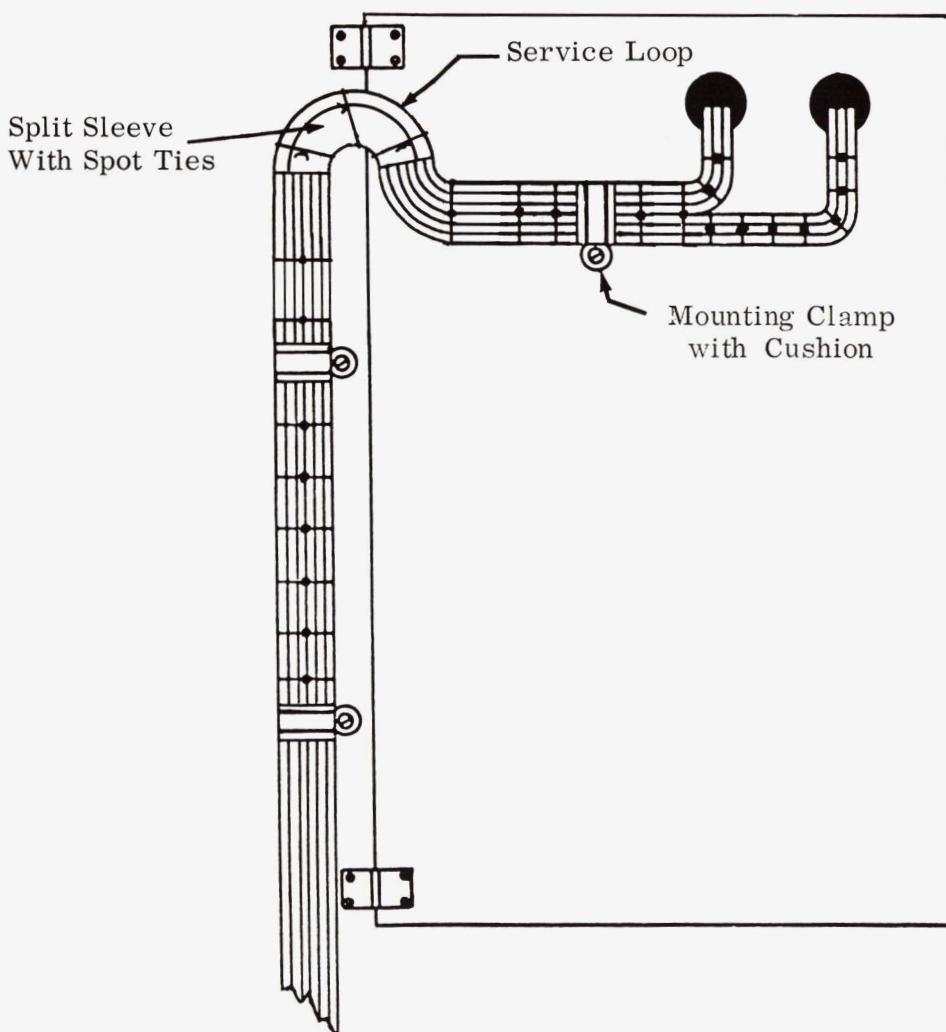


Figure 4-5. A service loop to allow opening an access door.

## **4.5 WIRE AND CABLE ROUTING**

### **4.5.1 APPEARANCE**

Wire harnesses shall have a neat, orderly appearance such as is achieved by combing of the wires and by progressive tying. (Refer to Figure 4-6.) Breakouts from a bundle shall be formed with a minimum number of crossed wires. Knots or kinks are not permitted in wire runs. (Refer to Figures 4-7 and 4-8.)

### **4.5.2 PROPER ROUTING**

Wiring shall be properly routed to:

- a. Eliminate the possibility of wire damage.
- b. Eliminate interweaving when crossing bundles.
- c. Provide accessibility for maintenance and inspection.
- d. Follow the most direct routing without causing the above discrepancies.

### **4.5.3 SUPPORTS**

Cables shall be supported by approved devices at intervals of not more than 15 inches. (Refer to Figure 4-17.) Wires and cables shall be properly supported and bound so as to:

- a. Secure wires and cables where routed through bulkheads and structural members.
- b. Prevent mechanical strain that would tend to break the conductors and connections.
- c. Provide maximum protection for the bundle conductors.

The first cable clamp from a connector shall not be more than 15 inches from the connector but not close enough to make coupling or uncoupling difficult (minimum of 3 inches). (Refer to Figure 5-7.)

## **4.6 BEND RADIUS OF WIRES, CABLES, AND HARNESSSES**

The minimum bend radius of an individual wire, bundle, or cable is measured as shown in Figure 4-10. The minimum radius of bend shall not cause cable insulation disruption nor affect normal cable life or characteristics. The minimum bend radius for cables or individual wires shall be 10 times the outside diameter of the cable or wire, except at terminal strips where the cable is suitably supported, the radius may be four times the diameter of the wire or cable.

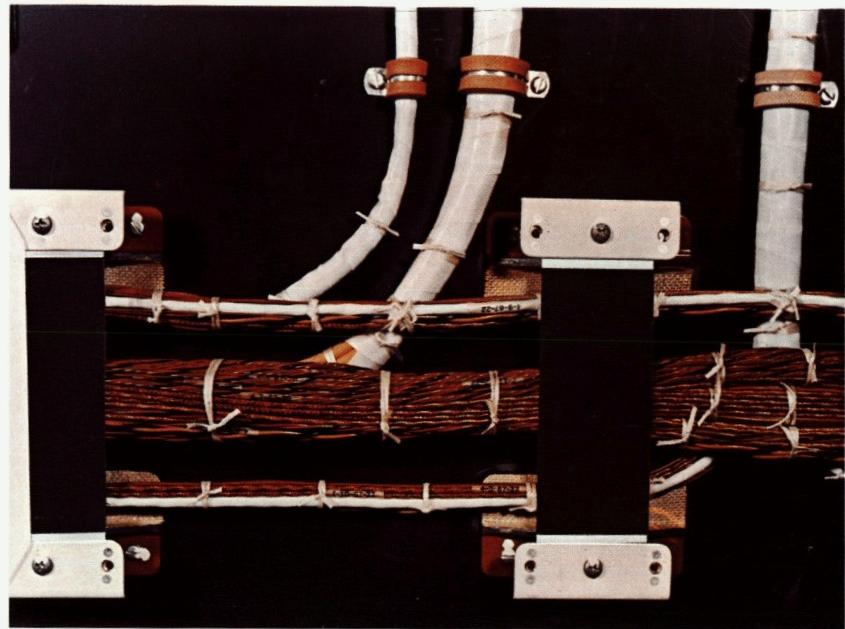


Figure 4-6. A neat, orderly appearance is achieved when wire bundles are properly combed and tied; however, wire bundles that cross should have been sleeved and tied.



Figure 4-7. A spot tie has been removed to show a kink of a wire within a bundle. This condition is not acceptable because knots or kinks are not permitted as means of taking up slack within a wire bundle.



Figure 4-8. Wire insulation has been deformed as a result of a doubled-back wire of tight bend radius.

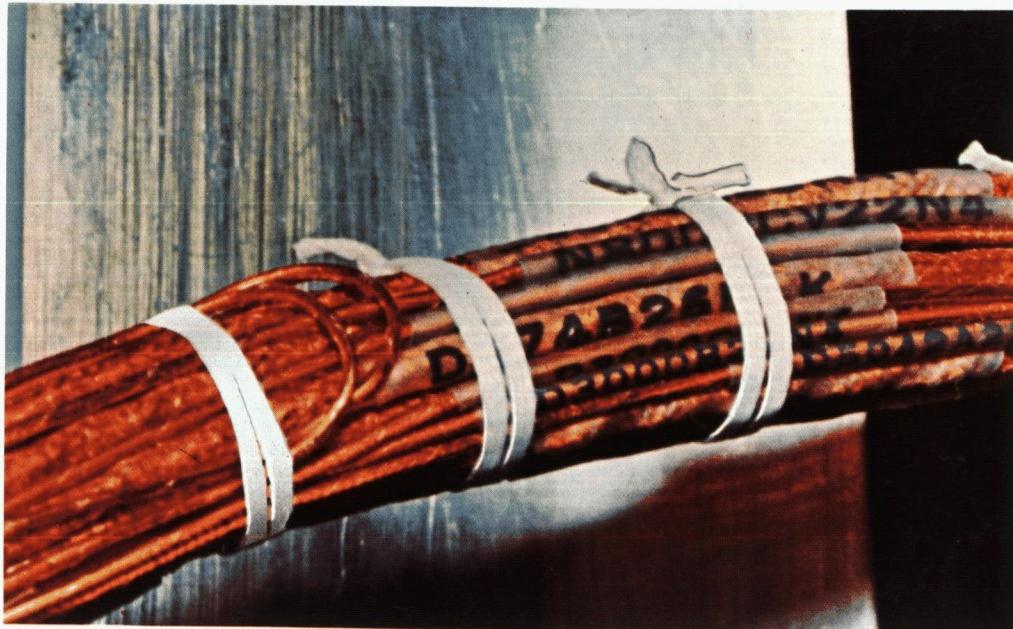


Figure 4-9. An example of an acceptable way of doubling back ground wires.

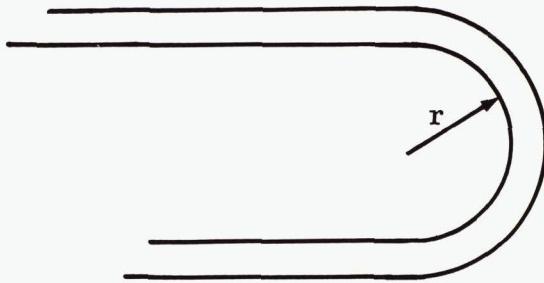


Figure 4-10. Measuring Bend Radius

#### 4.6.1 DEFORMATION

The minimum bend radius of wires and cables shall not cause deformation of insulation nor shall it affect normal wire characteristics. (Refer to Figures 4-8 and 4-9.)

#### 4.6.2 WIRE HARNESSSES

The bend radius for any individual wire or cable contained within the harness shall not be less than ten times the diameter of the largest wire or cable element within the harness. On shield terminations where the ground wire is doubled back on itself, the minimum bend radius is four times the diameter of the wire. (Refer to Figure 4-9.)

#### 4.6.3 COAXIAL CABLES

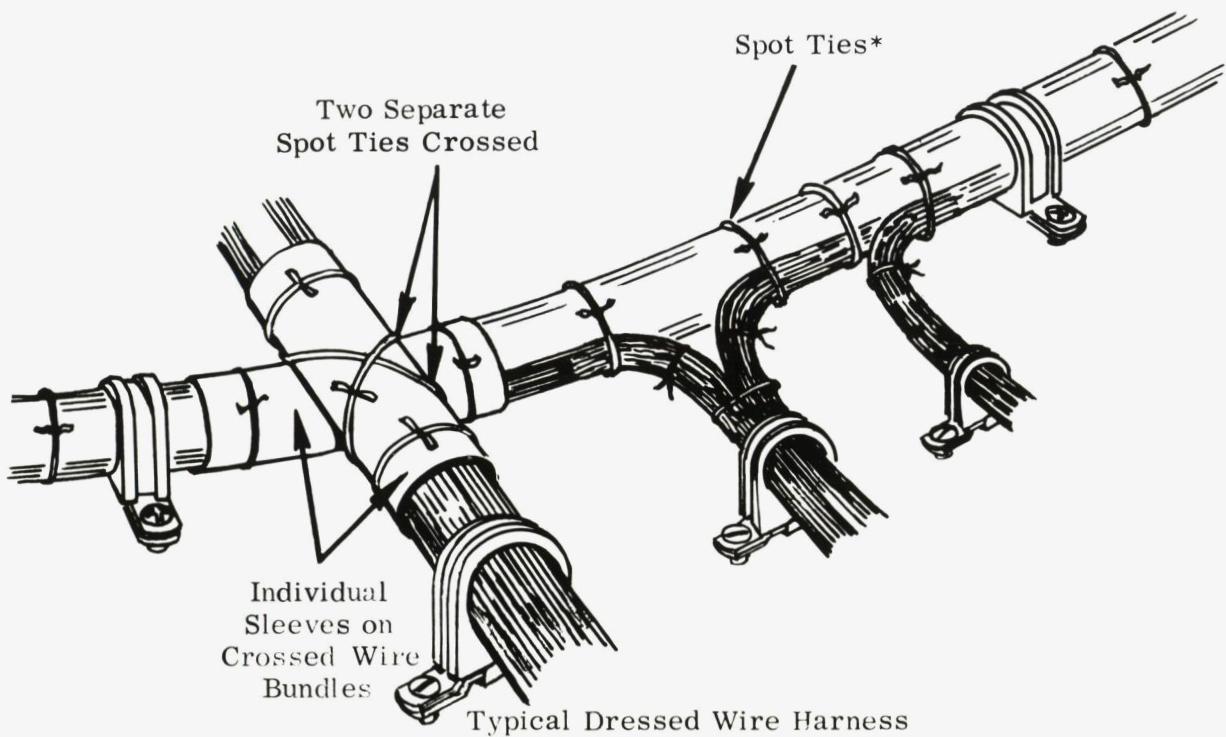
The minimum bend radius shall be ten times the cable diameter.

### 4.7 SEGMENT WIRE BUNDLES

Segment bundles should follow main trunk bundles to a point as near the final termination as possible before breakout. The segment bundles must be supported in the same manner as in the main trunk bundle after separation and prior to termination. (Refer to Figure 4-11.)

#### 4.7.1 BREAKOUTS

Breakouts from the main bundle shall be performed with a minimum of crossed wires. Figure 4-24 shows unacceptable wire breakouts. Wire bundle segments



\* Spot Ties Shall Be Uniformly Spaced As Follows:

<u>Wire Bundle Diameter</u>	<u>Spot Tie Spacing</u>
Up to 1/2"	Approximately 2"
1/2 to 3"	Approximately 3"
3" and Larger	Approximately 4"

Spot ties shall be installed before and after each breakout. The spot tie spacing may be closer than those listed above when required due to close spacing of terminations or when good manufacturing practice so dictates.

Figure 4-11. Spot ties used for wire breakouts and for crossed wire bundles.

shall be dressed and combed from their point of origin to their termination point (connector, terminal board, etc.). (Refer to Figures 4-6, 4-11, and 4-12.)

#### 4.7.2 DIRECTION AT BREAKOUTS

When breakouts of single or multiple wires are made at a cable support clamp, they will, where possible, be made in a direction away from the clamp-cushion wedge or clamp-mounting screw as is shown in Figure 4-13. If the cable must break out in both directions, it shall be spot tied at the clamp to prevent wire pinching caused by the clamp. (Refer to Figure 4-11.)

#### 4.7.3 SINGLE WIRE SUPPORT

A single wire to a terminal shall not extend more than 4 inches from the breakout without support as shown in Figure 4-14.

#### 4.7.4 BEND RADIUS AT BREAKOUTS

##### 4.7.4.1 Wires and Cables

The minimum bend radius of wires and cables at breakouts shall not cause insulation deformation or affect normal wire characteristics. (Refer to paragraphs 4.6.)

##### 4.7.4.2 Wire Harnesses

The wire harness or cable bend radius at breakouts shall be not less than ten times the diameter of the largest wire or cable in the wire bundle. (Refer to Figure 4-12a.)

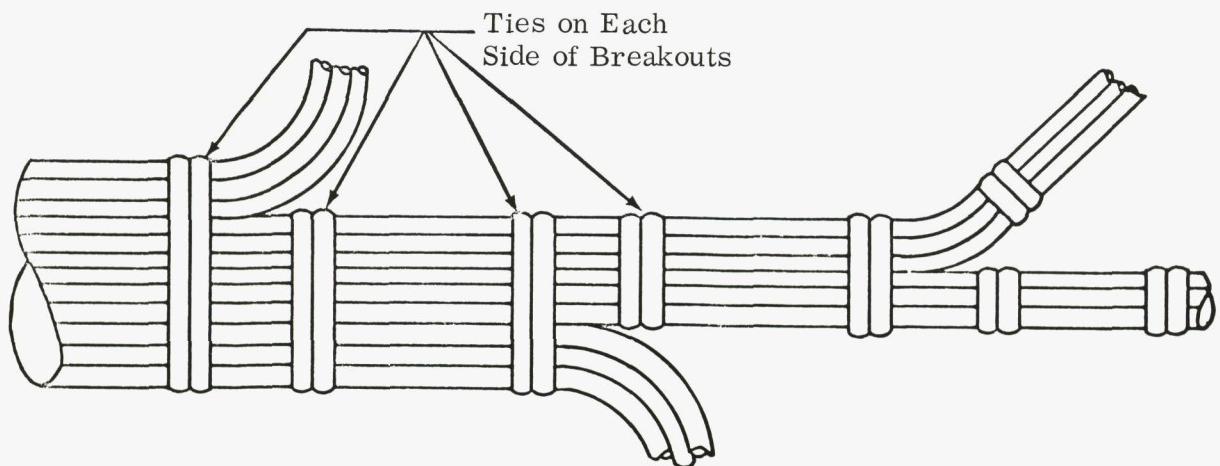
##### 4.7.4.3 At Terminals

At terminals, the bend radius of any individual wire shall be a minimum of four times the wire diameter. (Refer to Figure 4-12b.)

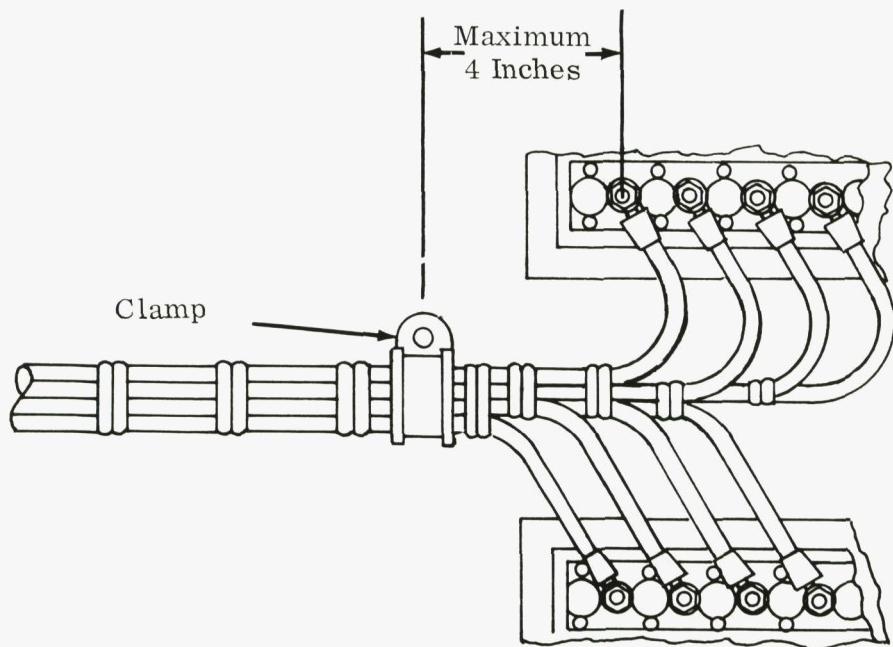
#### 4.8 WIRE AND BUNDLE DRESSING

##### 4.8.1 GENERAL

Wires which have been added to the harness shall be secured within the existing wire bundle.



a. Harness with Breakouts



b. Terminal Block or Junction Box

Figure 4-12. Breakouts from a wire bundle showing location of spot ties.

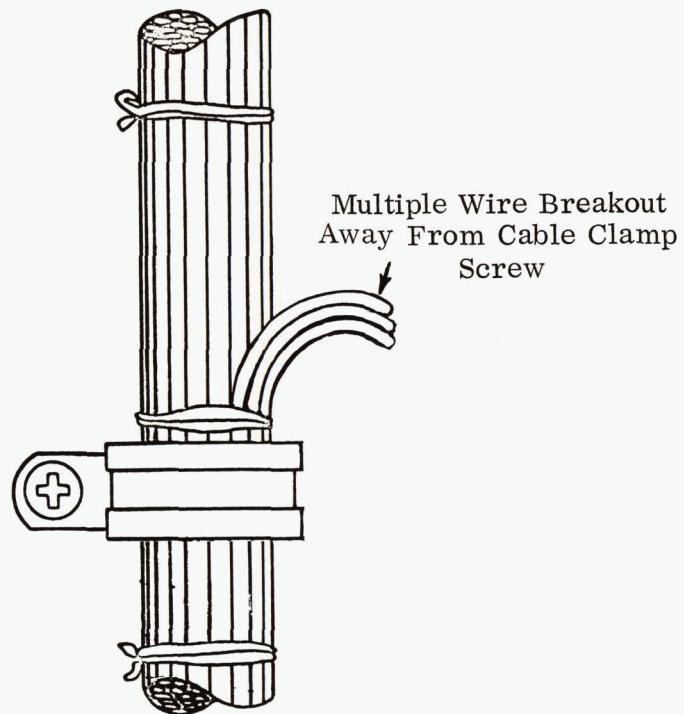


Figure 4-13. Method of Wire Bundle Breakout at a Clamp

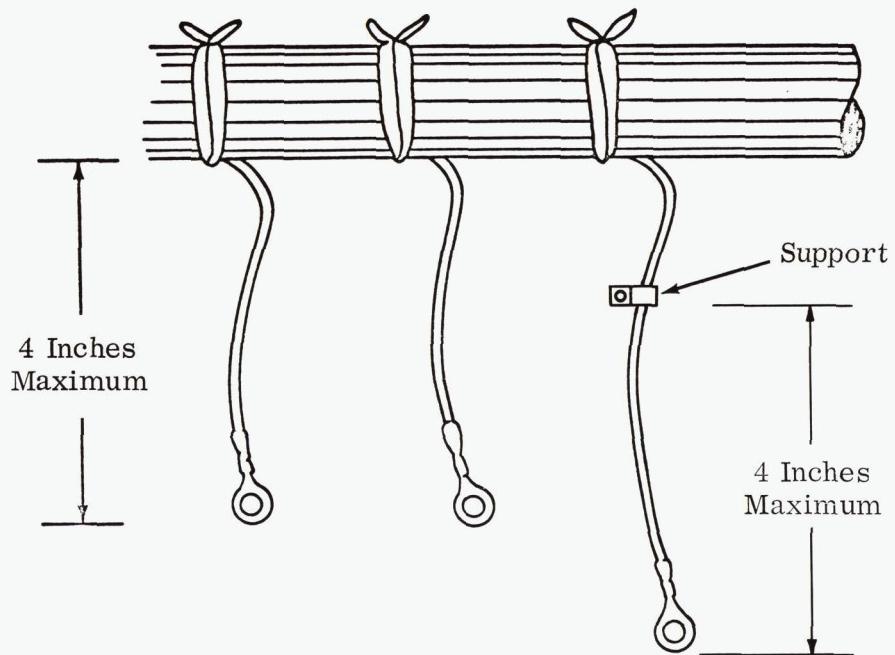


Figure 4-14. Minimum Support of Single Wire Breakouts

Wire harnesses shall be combed during rework to insure that wire runs remain parallel and do not cross other wires in the same bundle.

Bends in bundles shall be made with bundles untied to minimize tight wires.

Bundles being fabricated on three dimensional boards shall have the bends formed and the bundles tied prior to connector installation.

#### 4.8.2 END CAPS AND FERRULES

Spare wire end caps, splices, ferrules, etc., shall be so spaced as to preclude the possibility of multiple terminations at a single point in the wire bundle. (Refer to Figure 14-4.)

#### 4.8.3 SPOT TIES

Spot ties will be located around the complete bundle at intervals which provide support within 1/2 inch of the termination of spare wire end caps, ferrules, etc.

When two or more wire harnesses are to be grouped together to form one main bundle, individual spot ties shall be removed from each small harness. A sufficient number of spot ties (approximately every eight inches) shall remain in order to retain the identity of the small harness in the large bundle. (Refer to Figure 4-15.)

#### 4.8.4 UNDER CLAMPS

Splices, ferrules, spot ties, wire caps, and similar items shall not be located under clamps.

#### 4.8.5 REWORK

Any wires added as a result of rework shall be routed within the harness clamps to provide maximum protection for the wires.

In cases where wires are being added to existing harnesses, the original spot ties shall be removed, and new spot ties shall be added in approximately the same location, making the finished rework a unified bundle.

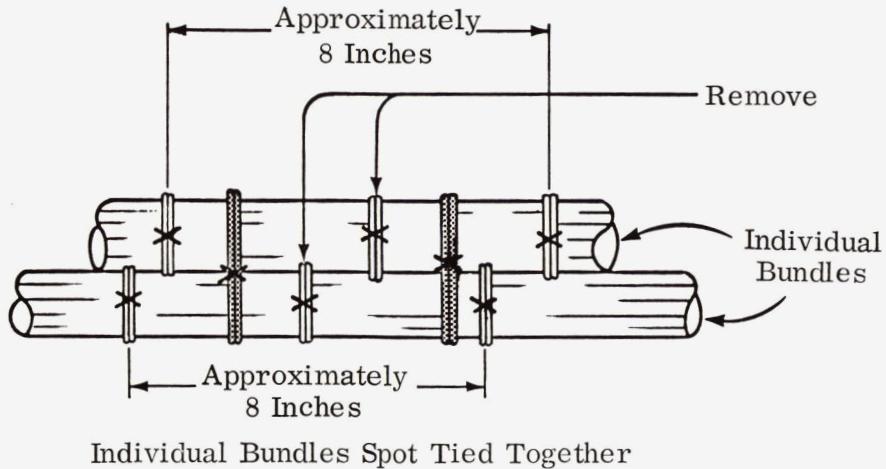


Figure 4-15. Combining Small Wire Bundles to Form a Larger Bundle. (Individual bundles shall not be spot tied together if installation drawings or electromagnetic compatibility needs demand physical separation.)

## 4.9 SLACK

### 4.9.1 PURPOSE

Slack in wire bundles between clamp installations shall be held to a maximum of 1/2 inch. (Refer to Figure 4-17.) Slack shall be provided for the following purposes:

- To permit ease of maintenance including connector coupling and uncoupling. (Refer to Figure 4-16.)
- To prevent mechanical strain on wiring, junctions, and wire supports. (Refer to Figure 4-17.)
- To permit movement of shock- and vibration-isolated equipment.

### 4.9.2 PROHIBITED USES

Slack shall not occur between the wire terminals and the first harness support clamp. It may occur between the first and third harness support clamps from the terminal and shall be as is shown in Figures 4-18 and 4-19.

Preferred location of connector identification is approximately 6 inches.

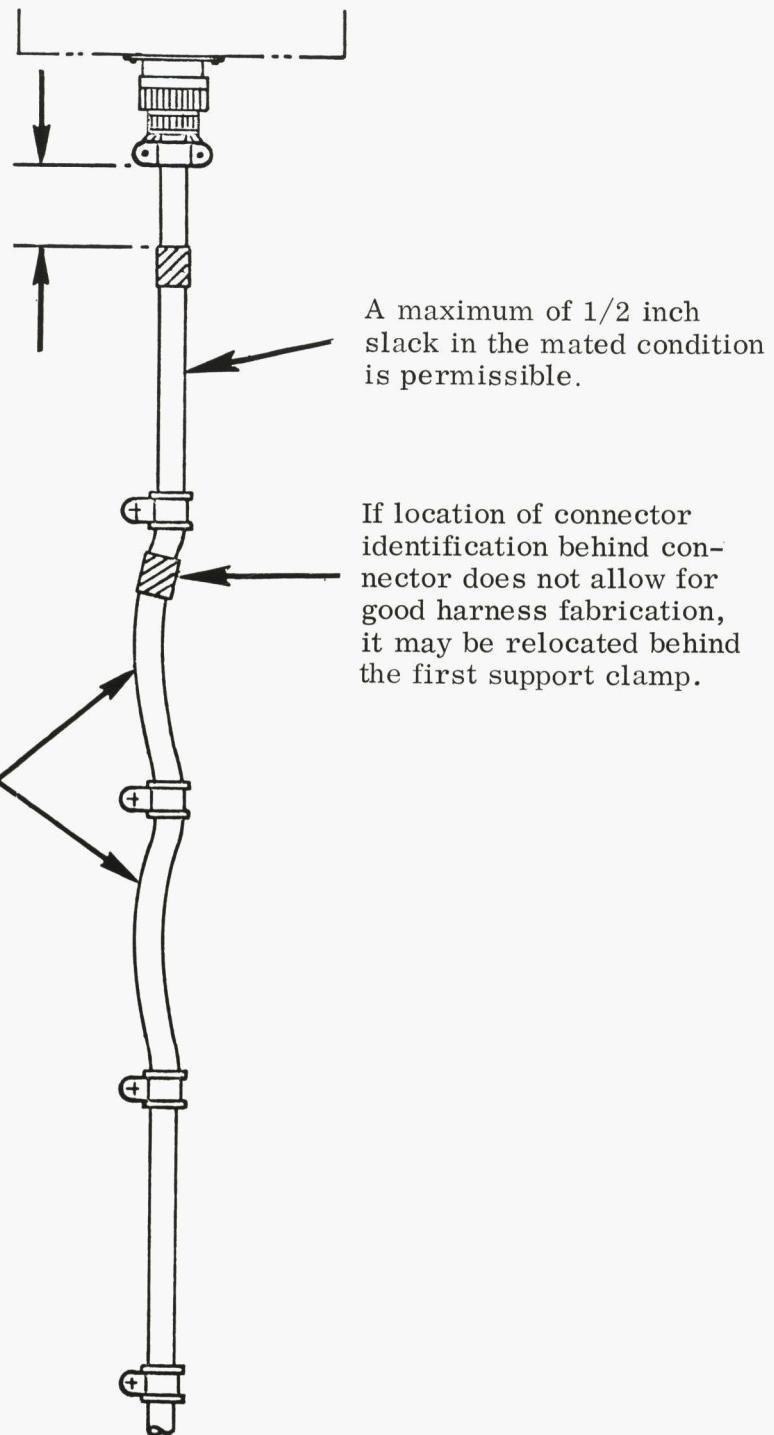


Figure 4-16. Approved Slack Allowances

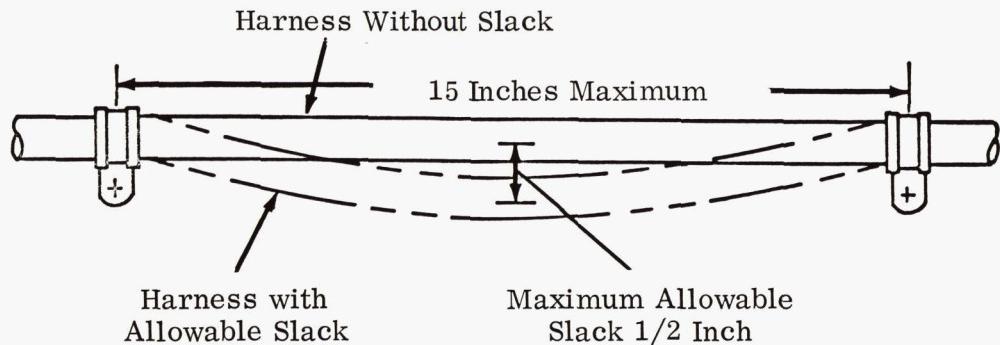


Figure 4-17. Maximum Distance Between Clamps to Reduce Strain on Wire Bundle

#### 4.10 SPOT TIES ON WIRE BUNDLES

##### 4.10.1 GENERAL

Approved spot ties shall be used on all wire bundles. They shall be used to prevent individual wires from departing from the run and be spaced to give the wire bundle a neat appearance.

Ties on individual multiconductor twisted cables shall not be required.

Spot ties shall be installed during wire bundle buildup to establish the wire routing configuration.

##### 4.10.2 TYPE OF KNOT

Spot ties shall be installed using a clove hitch with a double loop locking knot, unless otherwise specified. Ends of ties shall extend 3/16 to 3/8 inch from the knot. (Refer to Figure 4-20.)

Caution shall be exercised to assure that ties are tight enough to prevent sliding on the bundle but not too tight to deform the insulation of the individual wires.

##### 4.10.3 LOCATION

The first spot tie next to a connector shall be located where the funnel formed by the wires converges to the final diameter of the bundle. (Refer to Figure 4-21.)

Stud Type Terminal Strip

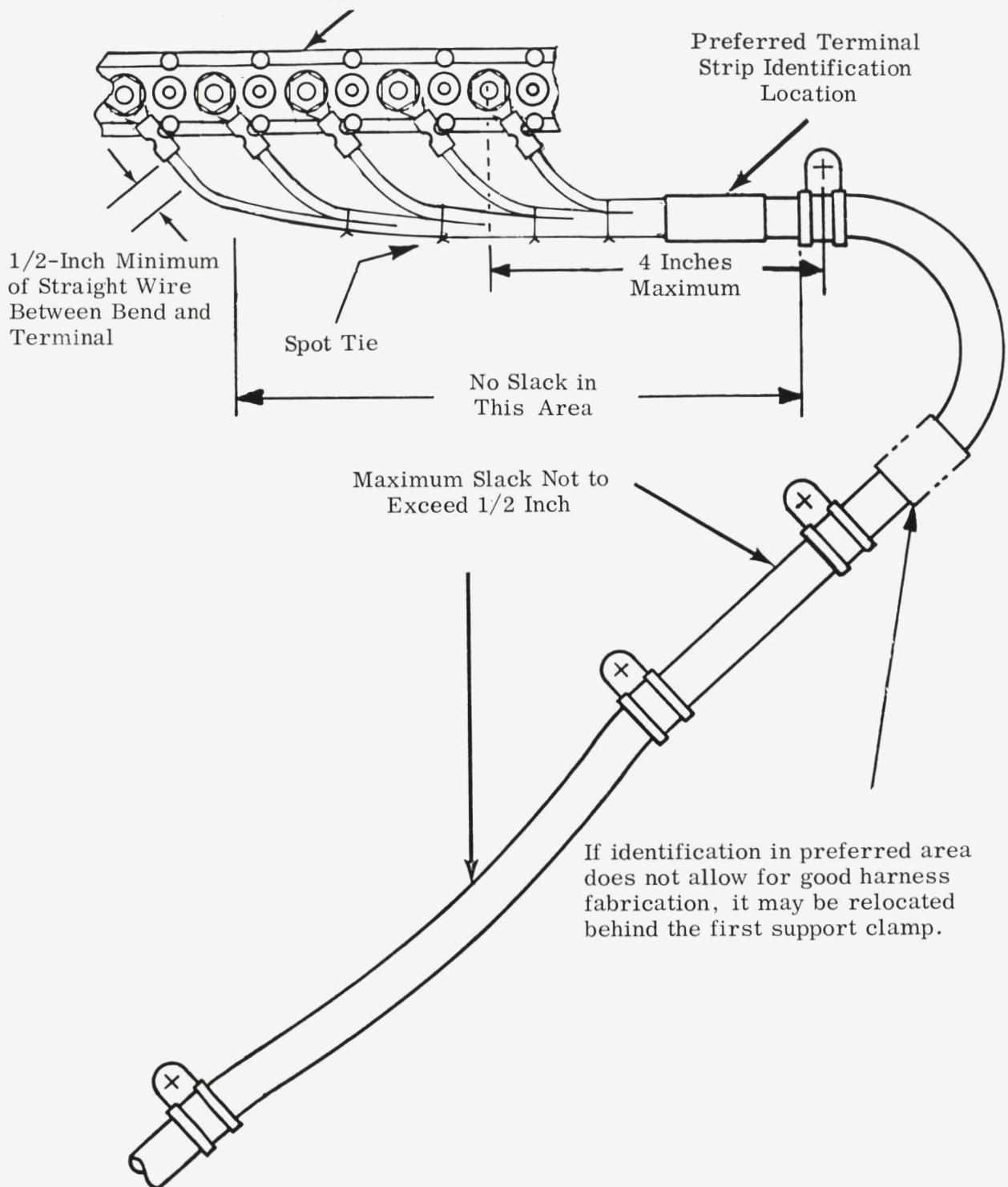


Figure 4-18. Approved Slack Between Stud Type Terminal Strip and Clamp

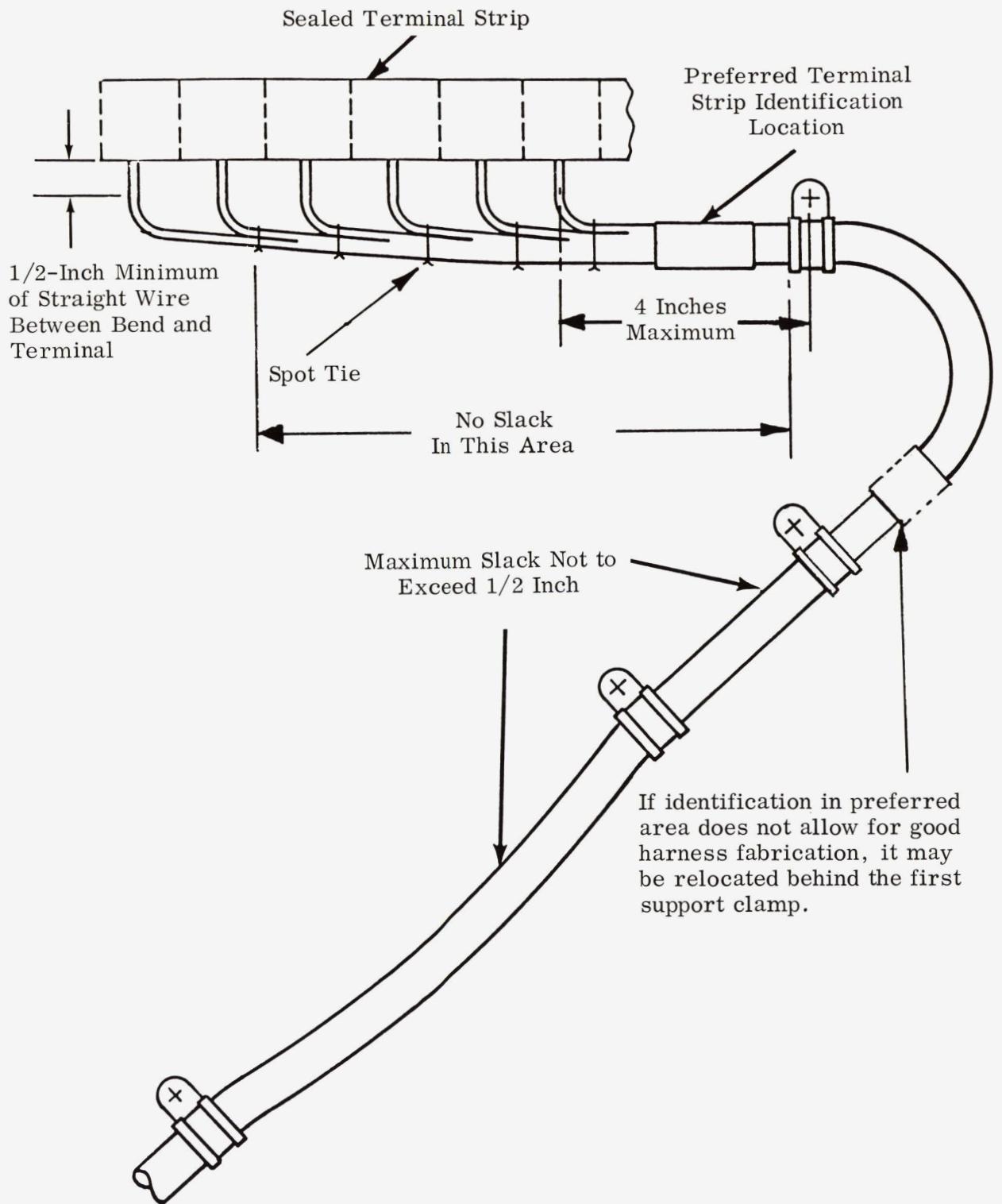
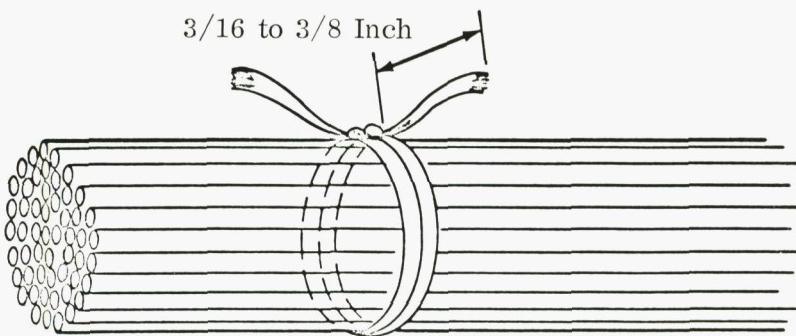
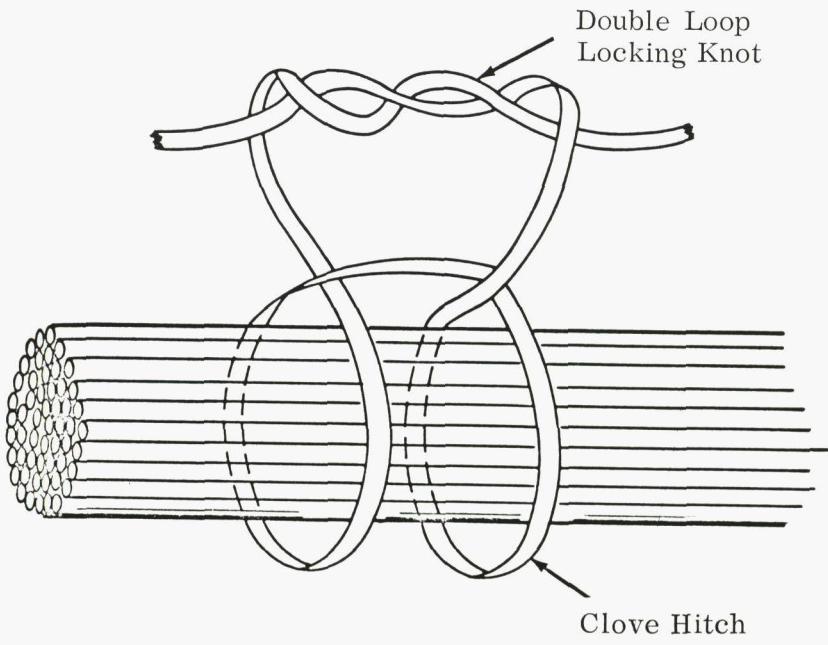
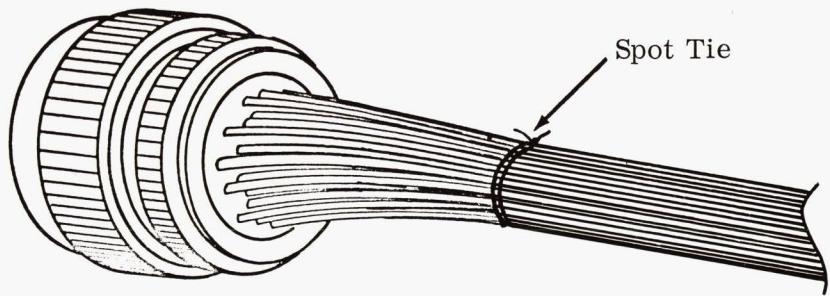


Figure 4-19. Approved Slack Between Sealed Terminal Strip and Clamp

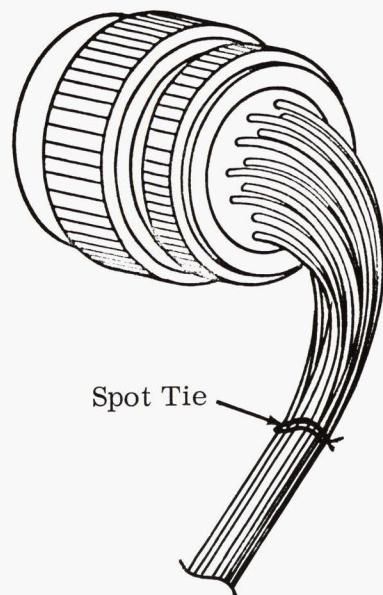


Typical Spot Tie

Figure 4-20. Approved Tie Knot



a. Straight Wire Harness



b. 90-Degree Bend Wire Harness

Figure 4-21. Spot ties located where funnel converges to final wire bundle diameter.

Spot ties shall be installed before and after each breakout. (Refer to Figures 4-11 and 4-12.)

#### 4.10.4 SPACING

Spot ties shall be uniformly spaced (Refer to Figure 4-11.) as follows:

<u>Wire Bundle Diameter</u>	<u>Spot Tie Spacing</u>
Up to 1/2 Inch	Approximately 2 Inches
1/2 to 3 Inches	Approximately 3 Inches
3 Inches and Larger	Approximately 4 Inches

The spot tie spacing may be closer than those listed above when required due to close spacing of terminations or when good manufacturing practice so dictates.

#### 4.10.5 PROHIBITED USES

Spot ties shall not be permitted under cable support clamps.

Spot ties shall not be used as primary support for wire bundles or cables.

Continuous lacing shall not be used unless approved by NASA.

#### 4.10.6 BUNDLES AT ANGLES

When two or more wire bundles cross at an angle, they shall be sleeved and spot tied as shown in Figures 4-11 and 4-22.

When a wire or cable is added to existing bundles which cross at an angle, spot ties will be added as shown in Figure 4-22. The main bundle ties shall not be disturbed.

#### 4.10.7 SLEEVE ADDITIONS

Spot ties will be used to secure protective type split sleeving and shall be installed 1/2 inch from each end as shown in Figure 4-23. Additional spot ties will be made at intervals necessary to prevent the split from opening.

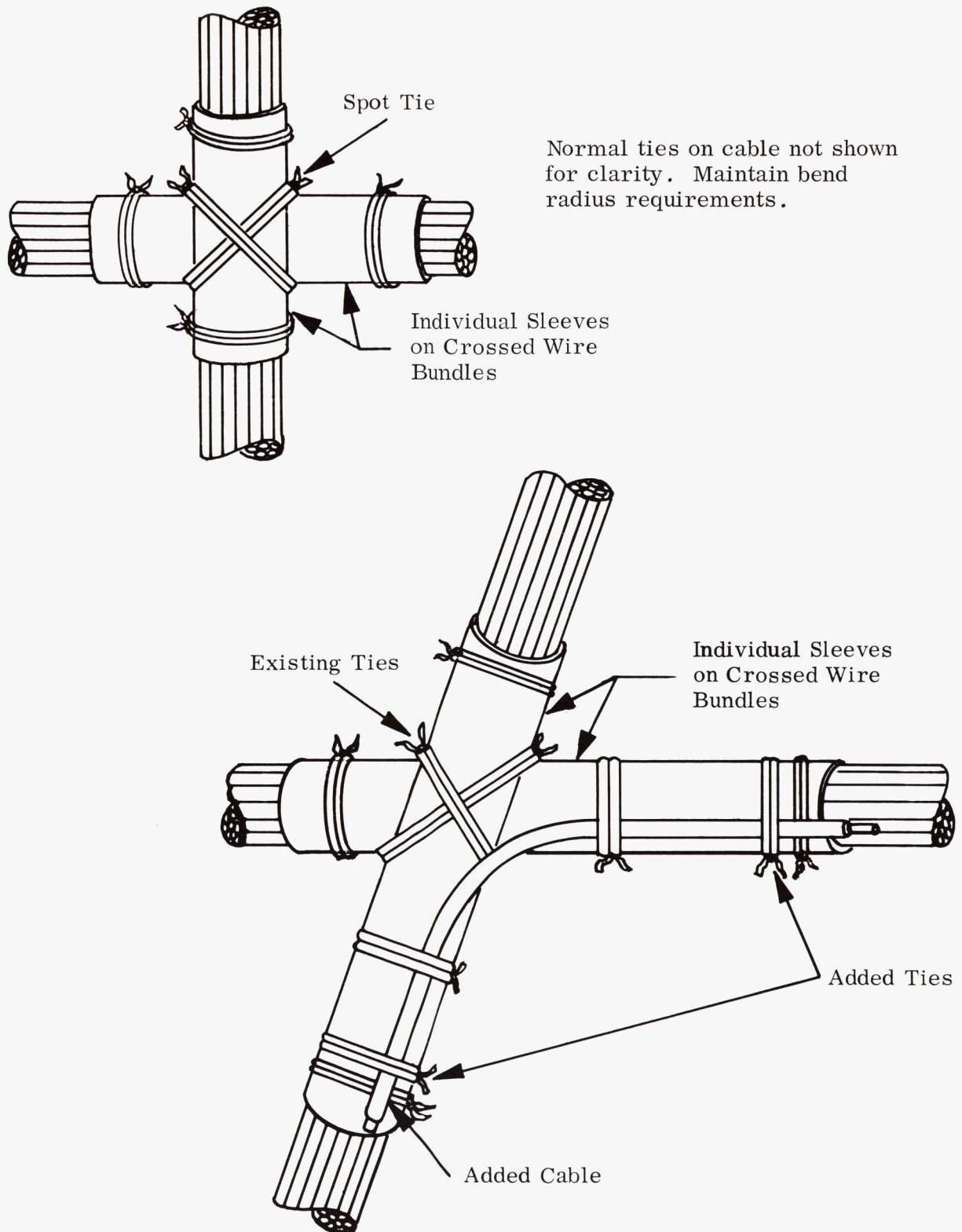


Figure 4-22. Sleeves and Ties on Crossed Wire Bundles

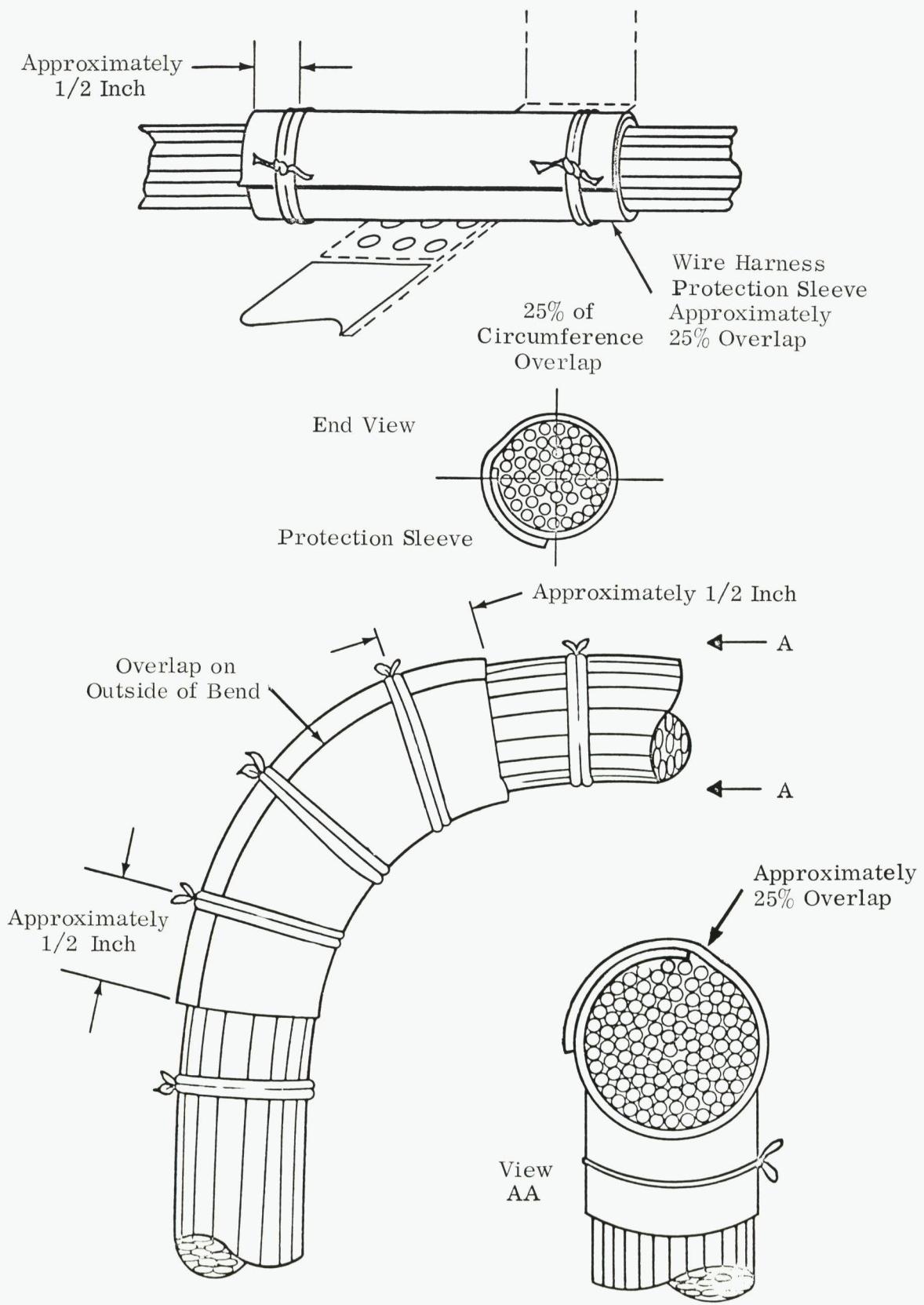


Figure 4-23. Split Sleeves and Ties On a Wire Bundle

#### 4.10.8 IDENTIFICATION TAG ADDITIONS

Spot ties may be used to secure identification name tags to wire bundles. Ties shall be secured as necessary to keep identification tags from moving.

### 4.11 SLEEVING AND WRAPPING

#### 4.11.1 GENERAL

Wire and wire bundles shall be inspected prior to installation of sleeving or wrapping.

Only approved sleeving of the proper size and type shall be used. If shrink sleeving is used, it shall be tight to the wire insulation and follow the contour of splices or components and form a tight seal at the ends. (Refer to Figures 4-25 and 8-2.) Zipper tubing shall not be used. If wrapping is used, it shall consist of non-adhesive approved tape of proper width, applied in a spiral fashion around the wire bundle. The exterior surface of sleeving and wrapping must be free of cracks, splits, cuts, etc. When shrink sleeving is used, there shall also be no evidence of overheating. (Refer to Figure 8-3.)

Wires and cables passing near hot or cold objects shall be protected against temperature extremes by the use of an appropriate insulating material.

#### 4.11.2 LOCATION

- a. Sleeving or other approved chafe-guarding material shall be placed around the wire bundle at any place where the bundle contacts or potentially contacts any other object that may chafe the bundle, even though the object already has a chafe guard. Sleeving shall be used on each bundle where two bundles cross and are spot tied together, as well as, in back of connectors with strain relief clamps. (Refer to paragraph 11.2.3.)
- b. Wrapping may be used on wire bundles where moderate wear due to handling or other personnel contact may be encountered and where a relatively smooth unabrasive surface may be contacted. Wrapping shall not be used where two bundles cross or when a bundle lays near sharp or abrasive surfaces.

#### 4.11.3 SPACING AND APPLICATION

- a. If sleeving is required under a clamp as a filler, the sleeving shall extend a minimum of 1/8 inch beyond the clamp. Where wire bundles cross, the sleeving shall extend a minimum of one inch on each side of the outer circumference of the bundles. Sleeving shall be placed on wire bundles at all exposed areas where damage may occur.
- b. Wrapping shall not be used indiscriminately. It shall be used only in locations described in 4.11.2 and shall not extend more than three inches or less than two inches on either side of the area of application. Wrapping shall be held in place by spot ties placed approximately 1/2 inch from each end approximately three inches apart. Wrapping shall overlap sufficiently to prevent gapping.

#### 4.11.4 SPLIT-SLEEVE INSTALLATION

In cases of rework or retrofit where shrink sleeving cannot be placed on the wire bundle, nonshrink sleeving shall be split and placed around the bundles at all locations as indicated in paragraphs 4.11.2 and 4.11.3. The sleeving shall be spot tied approximately 1/2 inch from each end and at intervals sufficient to keep the wrap from opening.

### 4.12 TORQUING AND TORQUE STRIPING

#### 4.12.1 EXTENT

Torquing shall be accomplished as follows:

- a. AN standards torque values will be used unless otherwise specified by applicable process specifications or drawings.
- b. Only calibrated torque wrenches shall be used for tightening terminations and mounting hardware.
- c. If an adapter is required, the torque wrench must be calibrated with the specific adapter to be used.

#### 4.12.2 TORQUE STRIPE APPLICATION

After torquing has been accomplished, a 1/16- to 1/8-inch wide stripe of an approved torque striping material shall be applied by Quality Control. (Refer to Figure 6-1.)

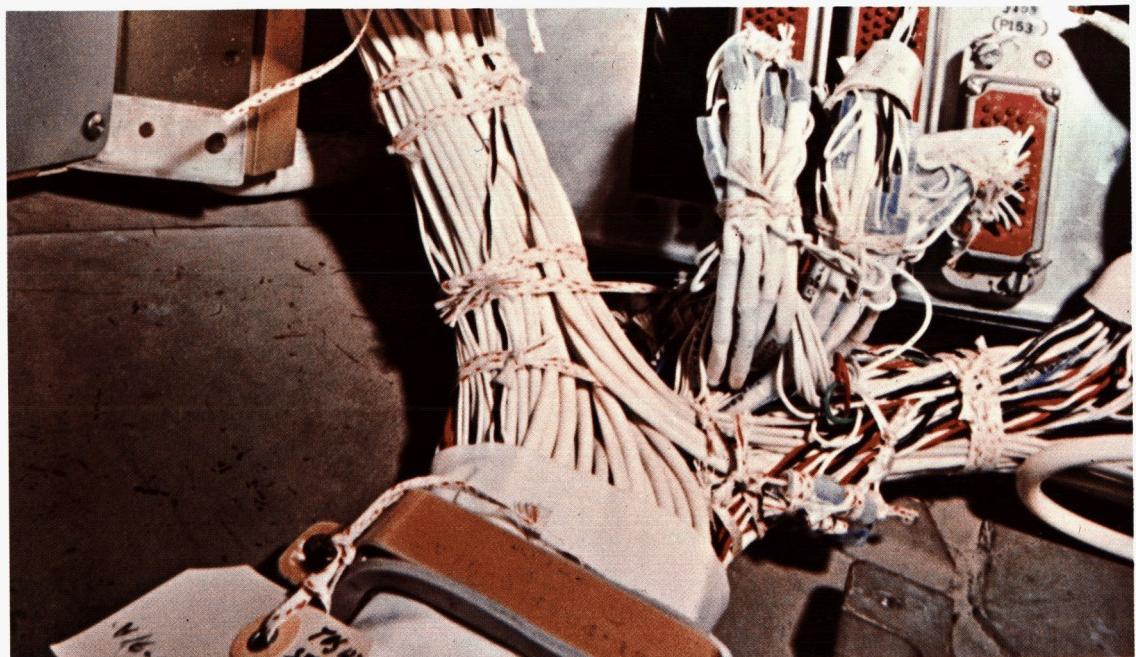


Figure 4-24. Unacceptable Wire Breakouts

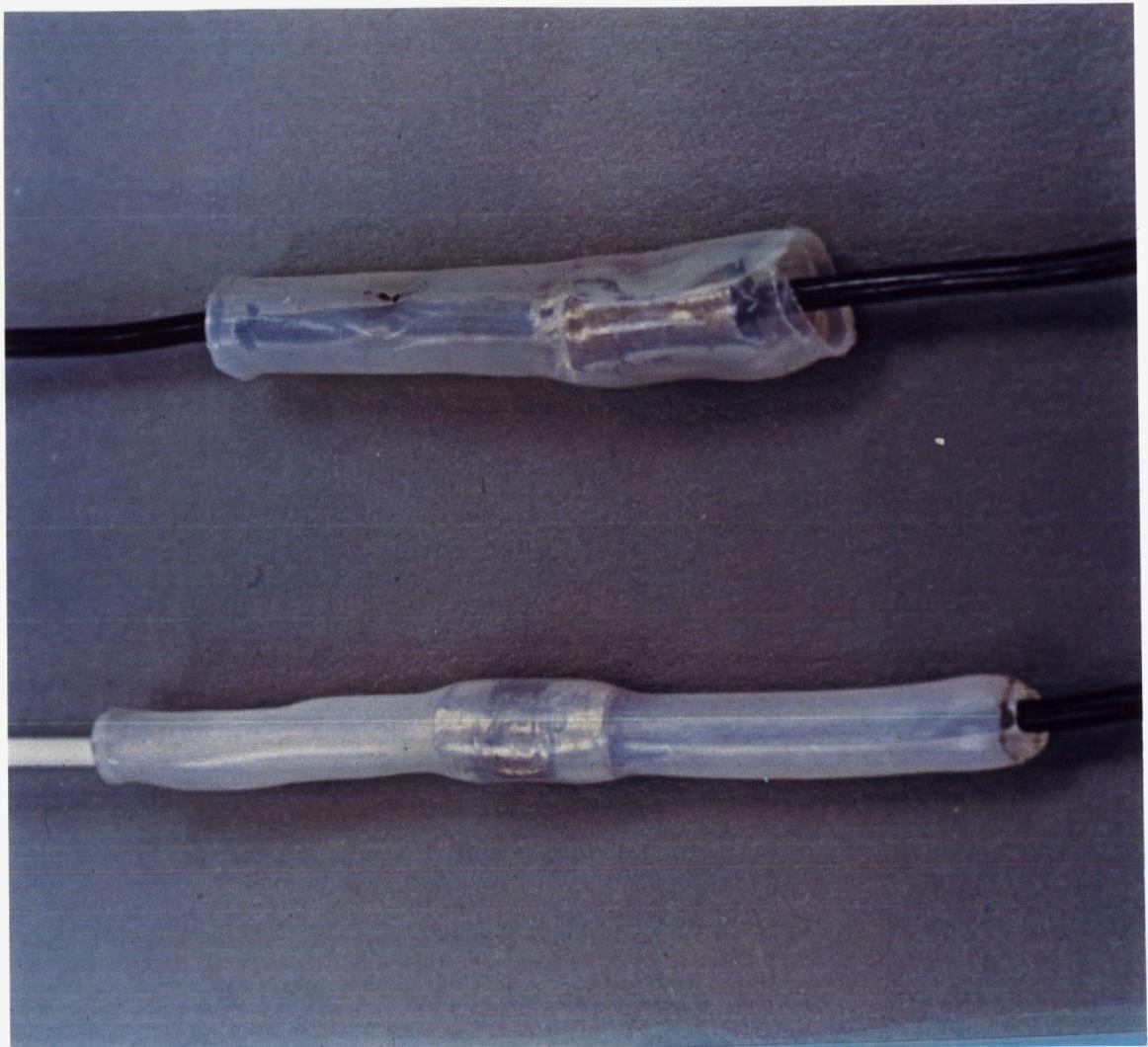


Figure 4-25. Heat Shrink Sleeves—Examples of Proper (lower) and Improper (upper) Shrinking

## **4.13 INSULATION**

### **4.13.1 GENERAL INSPECTION**

In addition to the required vendor tests and certifications, wire must be 100 percent inspected and tested at the user's facility prior to use, as follows.

- a. Visual examination for defects, discoloration, inclusions, splices, etc.
- b. For cleanliness.
- c. For dielectric strength.
- d. For insulation resistance.

In addition to the above, each spool of wire shall have approved samples taken which are to be tested for:

- a. Physical measurement of insulation, coating thickness, and concentricity.
- b. Resistance to cuts.
- c. Resistance to abrasion.

### **4.13.2 DAMAGE**

Any damage to insulation such as cuts, nicks, cracks, burns, etc., is cause for rejection.

## **4.14 TROUBLE SHOOTING**

When testing or trouble shooting requires probing, the wire insulation or flight connector shall not be probed with test leads. The flight connector must be demated and mated with a test connector. The pins of the test connector may then be probed with test leads. Under no circumstances shall flight connector pins or wire insulation be probed with test leads.

## SECTION 5

### SUPPORT AND CLAMPING OF WIRE

#### 5.1 GENERAL

Supports and clamps are used to keep the wire and wire bundles orderly, to reduce or eliminate vibration (no chafing), and to relieve strain on the wire bundles and connectors. The standards and specifications that apply to the fabrication of wire bundles shall also prevail during subsequent steps, including installation into the spacecraft and testing. It is essential that inspectors ensure that the initial wiring quality is maintained during these phases. The following paragraphs contain wire support and clamping criteria. Several illustrations are presented here, but additional illustrations occur in Section 4.

#### 5.2 WIRING SUPPORT

##### 5.2.1 APPROVED SUPPORT

Approved devices shall be used to support and to secure wires and wire bundles to:

- a. Prevent chafing. (Refer to Figures 4-6 and 9-3.)
- b. Provide clearance when wiring is routed through or adjacent to bulkheads or structural members.
- c. Maintain proper grouping during routing and in junction boxes and panels. (Refer to Figure 5-1.)
- d. Prevent mechanical strain that would break the wiring or connections. (Refer to Figure 5-3.)
- e. Facilitate wiring or re-assembly of terminal boards.
- f. Prevent excessive movement under vibration.

##### 5.2.2 INSPECTION

In inspecting for proper wiring support, the following conditions shall be cause for rejection:

- a. Wires, cables, or bundles supported by any fluid line (gas or liquid) or wire spacing support that is fastened to a fluid line. (Refer to Figure 5-2.)

- b. Wiring clamps, bonding jumpers, or electrical terminations installed under primary structure fasteners.
- c. Spot ties that are used as primary support for wiring.
- d. Wires, sleeving, or other materials on bundles located between mounting tabs on cable clamps or between contact surfaces of terminals or bus bars.

### 5.3 CLAMPING DEVICES

Wire harness clamping devices shall be of size and type to hold the wires firmly after fastening, without damage and without changing the cross-sectional shape of the wire bundle. Figure 5-4 is an example of a clamp that is not small enough to hold the wire bundle firmly. Refer to Figures 5-5 and 5-6 for illustrations of wire bundles with clamp installations shown as not acceptable and acceptable, respectively.

The following criteria shall be used in inspection of clamps:

- a. The size of the clamp shall permit the mounting tabs of the clamping device to meet without deformation to the wire bundle while gripping the bundle firmly. (Refer to Figures 5-5 and 5-6.)
- b. Wiring shall never contact the bare metal of clamping devices.
- c. Washers or other spacer devices shall not be installed between the mounting tabs of clamping devices.
- d. Mounting hardware that secures the clamps shall be properly installed, torqued, and torque striped.
- e. Deformation of the clamp or damage to the clamp cushion material shall be cause for rejection. (Refer to Figure 5-5.)
- f. The distance between the first clamp and the back of the connector potting and/or sealing material shall be no less than three inches nor greater than 15 inches. (Refer to Figure 5-7.)

#### 5.3.1 SINGLE-LOOP CLAMPS

All single-loop clamps shall be installed in accordance with the wire bundle installation print. Whenever an addition or deletion of wiring is required, the clamps shall be increased or decreased in size to fit the new installation as appropriate. If the new clamp will not grip the wire or cable firmly (Refer to Figure 5-4.) an approved type of filler shall be added. (Refer to Figure 5-8.)



Figure 5-1. In addition to unacceptable wire routing and dressing, the clamp crushes the wires and is not large enough to contain all bundles (notice one bundle by-passes clamp).

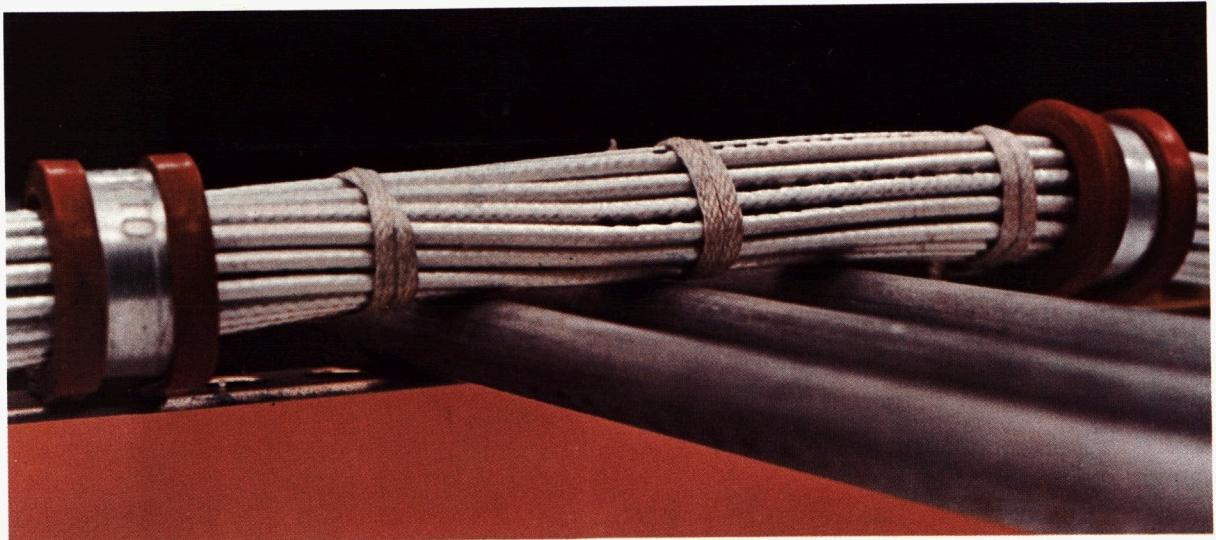


Figure 5-2. The wire bundle is properly clamped to prevent vibration, but the 1/2-inch minimum clearance between wire bundle and fluid lines does not exist.

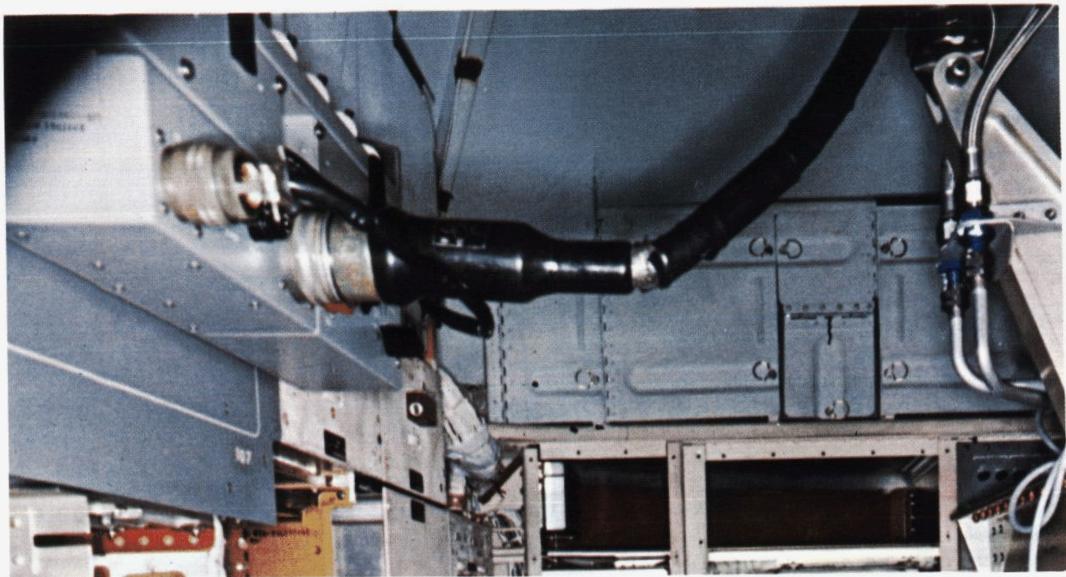


Figure 5-3. This GSE cable was damaged because it was not properly supported. Undue strain was also placed on the flight equipment connector.



Figure 5-4. An example of a clamp that is not small enough to grip the bundle firmly. A smaller size clamp or filler material should have been used.

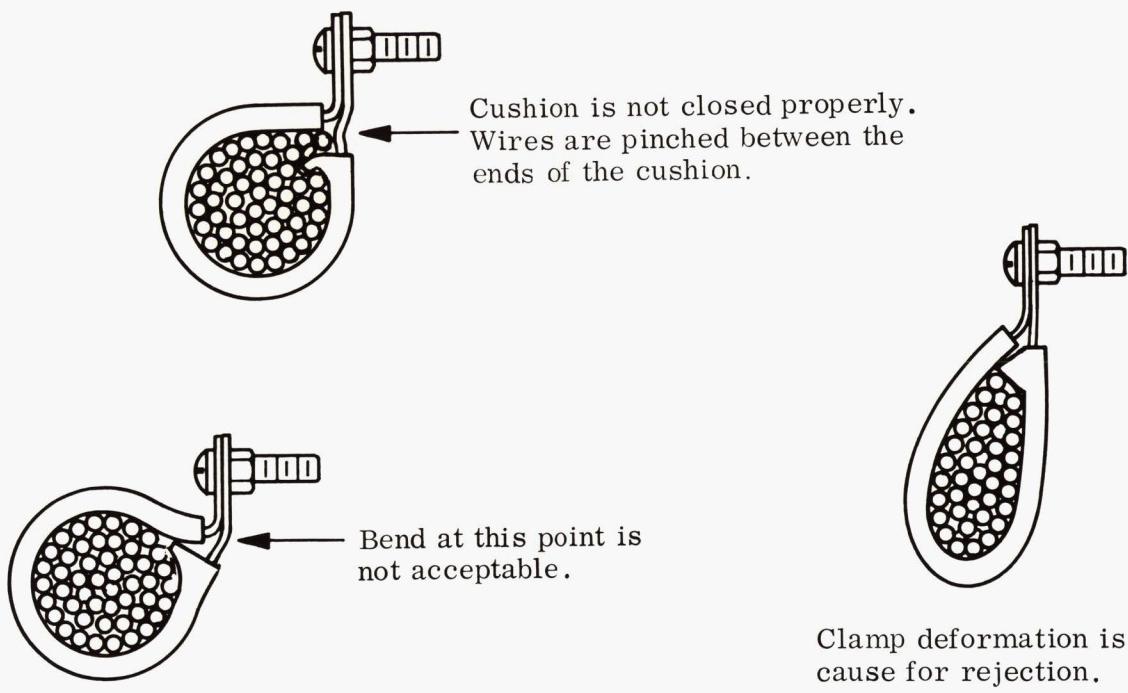


Figure 5-5. "Not Acceptable" Clamp Installations

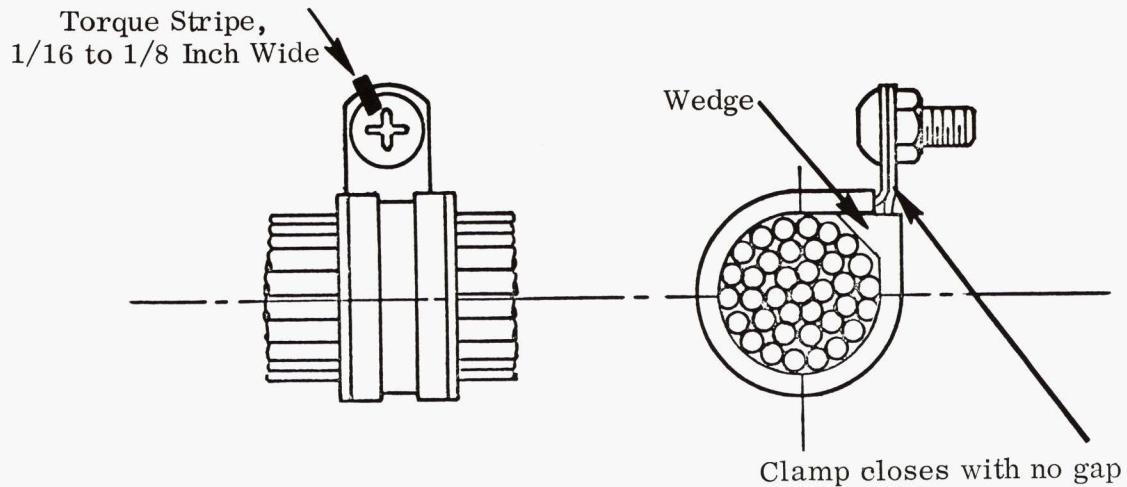


Figure 5-6. An Acceptable Clamp Installation

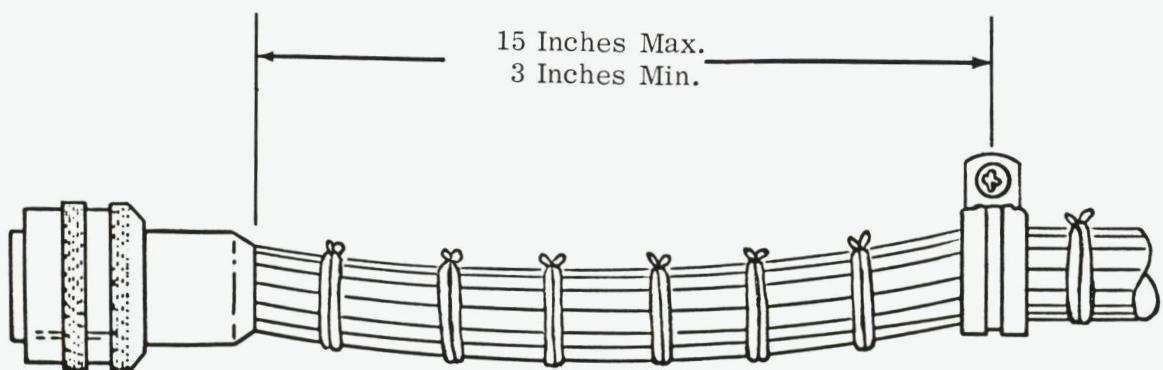


Figure 5-7. Maximum and Minimum Support Distances Shown From Connector To Clamp

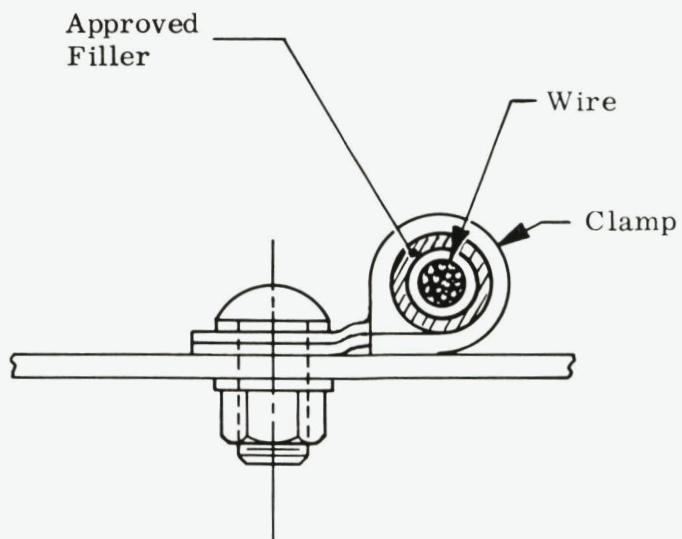


Figure 5-8. Clamp With Filler

### 5.3.2 SPECIAL-TYPE CLAMPS

Any clamp installation other than the single-loop type shall be termed a special type and shall only be used when approved by NASA. When a special type of clamp is used and if it does not hold the wire bundle firmly, a suitable spacer or filler shall be used to insure that the bundle is firmly gripped. The type of spacer or filler must be called out on the wire bundle installation print. (Refer to Figure 5-9.)

### 5.3.3 WOVEN-GLASS RESTRAINT DEVICES

Woven glass bonded restraint devices shall not be used as primary support for wire bundles.

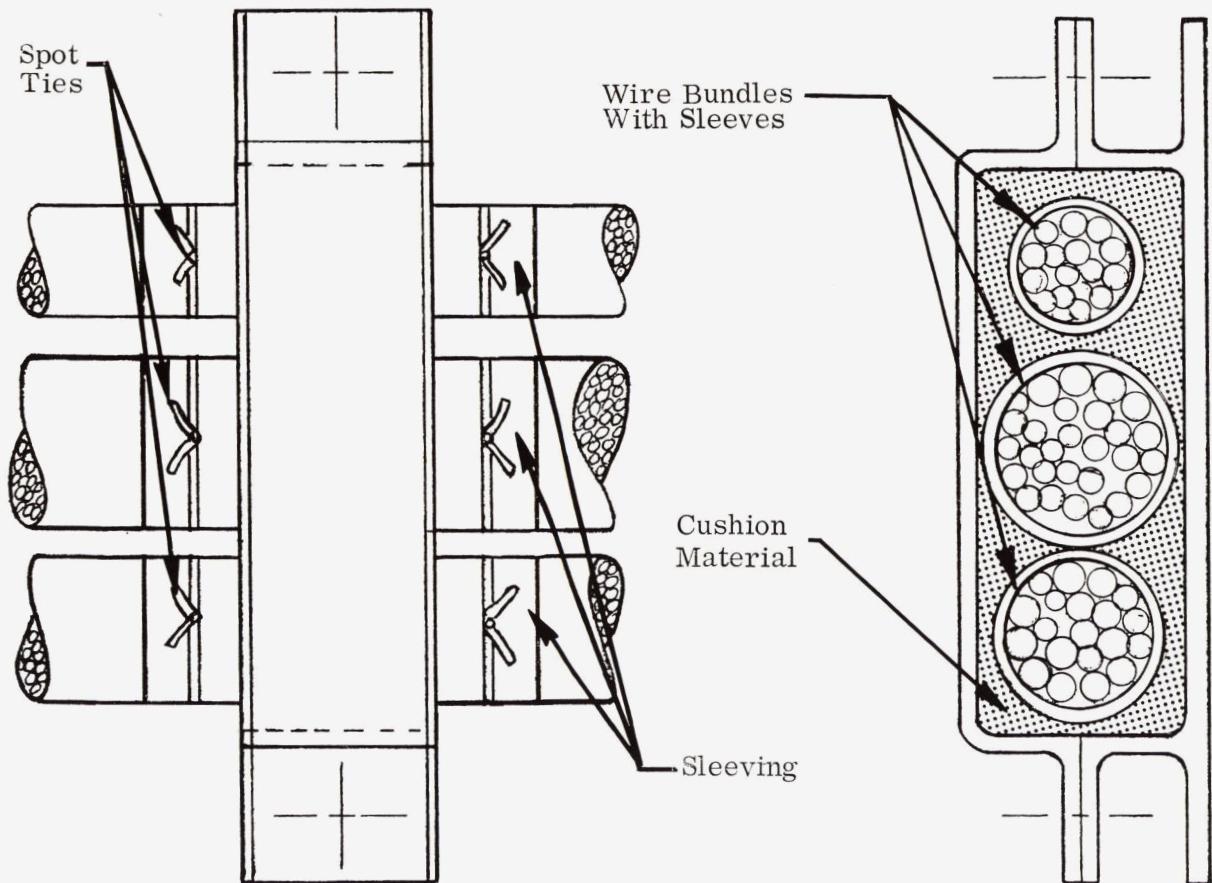


Figure 5-9. A Special Type of Clamp With Protective Cushion Filler Material

SECTION 6  
MECHANICAL AND SOLDERED TERMINAL CONNECTIONS

**6.1 GENERAL**

This Section covers the inspection criteria to be used for stud-type terminal barrier strips, sealed terminal strips, crimped contact connectors, soldered terminal connections, and electrical bonding. These criteria and standards are supplemental to the following documents referenced in paragraph 1.3.2:

- a. MSC-ASPO-S-5C, MSC-ASPO Soldering Specification
- b. MSC-ASPO-S-6A, MSC Supplement to NPC 200-4—June 1, 1966
- c. MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections

**6.2 STUD-TYPE TERMINAL BARRIER STRIPS**

**6.2.1 PREPARATION OF TERMINAL STRIPS**

Terminal strips that have bottom stud cavities shall have had the cavities sealed in accordance with applicable process specifications before installation in the space-craft. Prior to the installation of lugged wires, each terminal barrier strip shall be inspected for scratches, broken separator posts, and missing base insulating strips; and all studs shall be free of lacquer, paint, primer, and any other foreign matter.

**6.2.2 WIRES WITH CRIMPED LUGS**

Crimped terminal lugs which are affixed to wires for use on stud-type terminal barrier strips shall be inspected as follows.

**6.2.2.1 Wire Preparation**

Prior to crimping terminal lugs onto wires, inspection will verify the following:

- a. Insulation has been etched in accordance with the requirements outlined in Section 10.
- b. Wires have been stripped in accordance with the applicable process specification.

- c. The stripped portion of conductor is clean and has no missing, nicked, or damaged strands.
- d. The natural twist or "lay" of the strands in the conductor has not been disturbed; however, minor disturbances may be restored.

#### 6.2.2.2 Crimped Terminal Lugs

Crimped terminal lugs shall be as specified on the applicable engineering drawing.

#### 6.2.2.3 Crimping Tools

Crimping shall be accomplished with calibrated crimping tools as specified in the applicable process specification. Refer to MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections, and to Section 13 for crimping tool certification and control requirements.

#### 6.2.2.4 Crimped Lug Inspection

After crimping, terminal lugs shall be inspected for the following characteristics:

- a. Wire insulation shall not extend into the crimped portion of the terminal lug barrel.
- b. The protruding end of the crimped wire shall be at least flush with the front end of the terminal barrel and shall not protrude more than 1/32 inch.
- c. There shall be no damage to the wire insulation.
- d. The crimp indentation shall be properly formed and located.
- e. The wire insulation support barrel shall grip the wire insulation firmly.
- f. There shall be no cracks, splits, or other-than-intended deformation of the lug or barrel.

### 6.2.3 INSTALLATION

The following shall be used as inspection criteria:

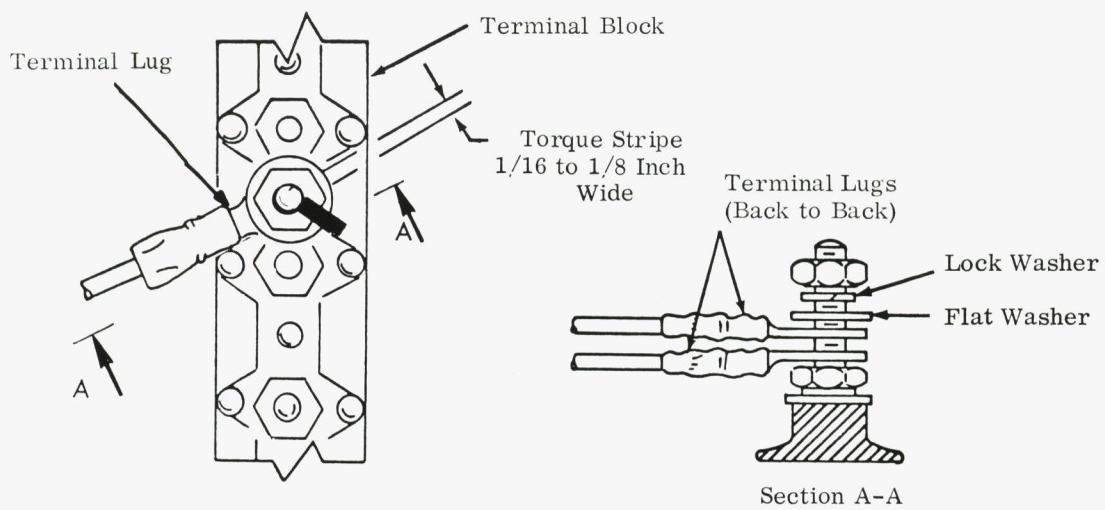
- a. When terminal lugs are attached to one or both sides of a terminal block, the terminal lugs shall be installed in the following order:  
(Refer to Figure 6-1.)
  - (1) Beginning at the bottom of the stud, the first and second terminal lugs shall be installed back to back.

- (2) A flat washer and lock washer of the appropriate sizes and types shall be installed next if there are only two lugs.
  - (3) For four lugs, the third and fourth terminal lugs shall also be installed back to back, and the remaining hardware shall then be installed.
  - (4) A 1/16 to 1/8 inch-wide torque stripe (of an approved type of torque striping paint) shall be applied after the torque operation has been completed.
- b. A maximum of four terminal lugs may be installed on any one terminal block stud. (Refer to Figure 6-1.) With the exception specified in paragraph c below, not more than two terminal lugs shall be installed on any one side of a terminal block.
  - c. In cases where it is required to install more than two terminal lugs on a terminal block stud and when only one side of the terminal block may be utilized, a maximum of three lugs shall be installed as follows: (Refer to Figure 6-2.)
    - (1) Beginning at the bottom of the stud, the first and second terminal lugs shall be installed back to back.
    - (2) A washer of the appropriate size and type shall be installed next.
    - (3) The third terminal lug shall be installed, and the remaining hardware shall then be installed.
    - (4) A 1/16 to 1/8 inch-wide torque stripe (of an approved type of torque striping paint) shall be applied after the torque operation has been completed.
  - d. Each terminal stud shall be inspected to determine the presence of a flat washer next to the top terminal lug with a lock washer between the flat washer and the nut. (Refer to Figure 6-2.) A missing flat washer shall be cause for rejection.

#### NOTE

If self-locking nuts are utilized,  
lock washers shall be omitted.

- e. After all nuts have been installed, the terminal barrier strip shall be inspected for damaged threads on the terminal studs. (Terminal lugs shall have been installed in such a manner that tightening of the nut on



( Torque stripe shall extend from the nut to the base of the terminal block. )

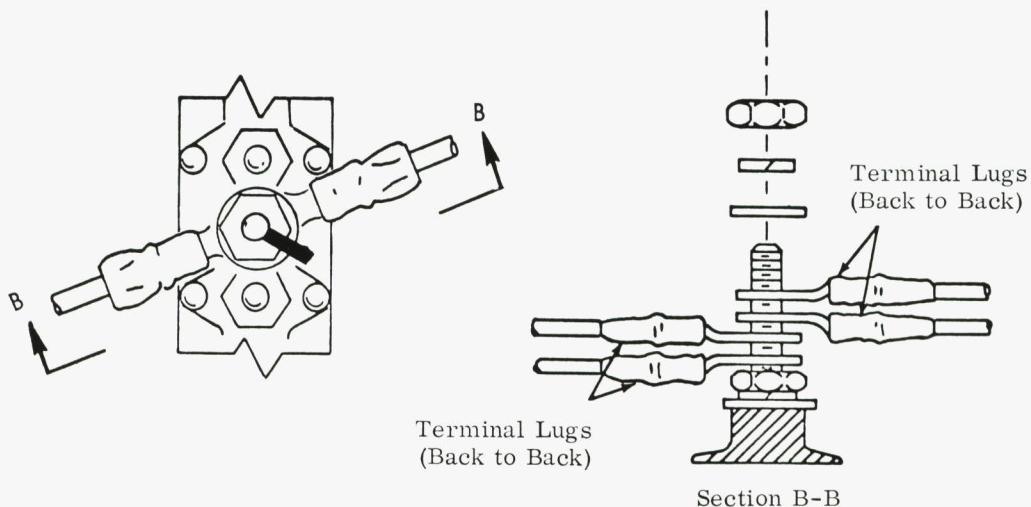


Figure 6-1. Installation of Terminals on Terminal Block

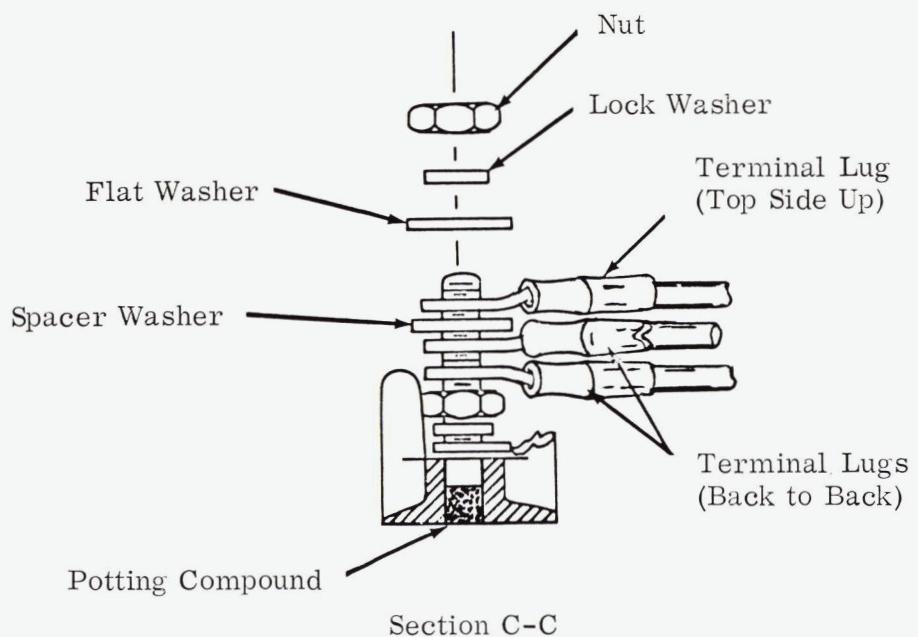
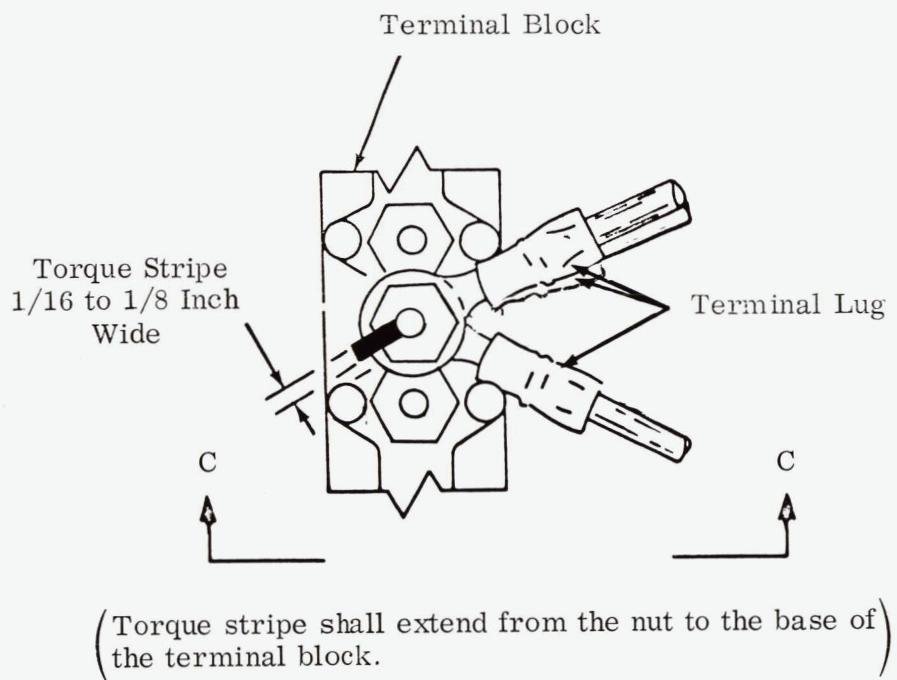


Figure 6-2. Installation of Three Terminals on One Side of Terminal Stud

the stud did not deform or damage the lug or stud.) The upper terminal lug shall be against the right hand barrier post when the final torque is made in accordance with the applicable process specification or drawing.

#### 6.2.4 PROTECTION

The following criteria shall be used in protecting the barrier strips:

- a. The assembled terminal barrier strips and associated wires shall have applied a conformal coating of the appropriate thickness as specified in Section 10. All terminal strips that are not conformal coated shall be rejected.
- b. Terminal strips that have bottom stud cavities shall have the cavities sealed in accordance with applicable specifications before installation.
- c. Terminal strips shall be protected with the conformal coating even though they are equipped with protective covers.
- d. Wires or wire bundles that are routed to a terminal strip shall be strapped or clamped as close to the terminal strip as is practical. The maximum distance from the strap or clamp to the first terminal that is used shall not exceed four inches. (Refer to Figures 4-18 and 4-19.)

#### 6.2.5 FINAL INSPECTION

The following shall be cause for rejection:

- a. Base insulating strip missing.
- b. Broken separator posts.
- c. Insulating cover, when specified, over terminal studs missing.
- d. Damaged threads on terminal posts.
- e. Terminal lugs improperly installed.
- f. Damaged or lack of conformal coating (exposed conductors).
- g. Missing or misaligned torque stripes.
- h. Lock washers or flat washers missing.
- i. Improper mounting.
- j. Deformed or damaged lugs.
- k. Missing hardware on spare terminal posts. (Refer to Figure 6-3.)

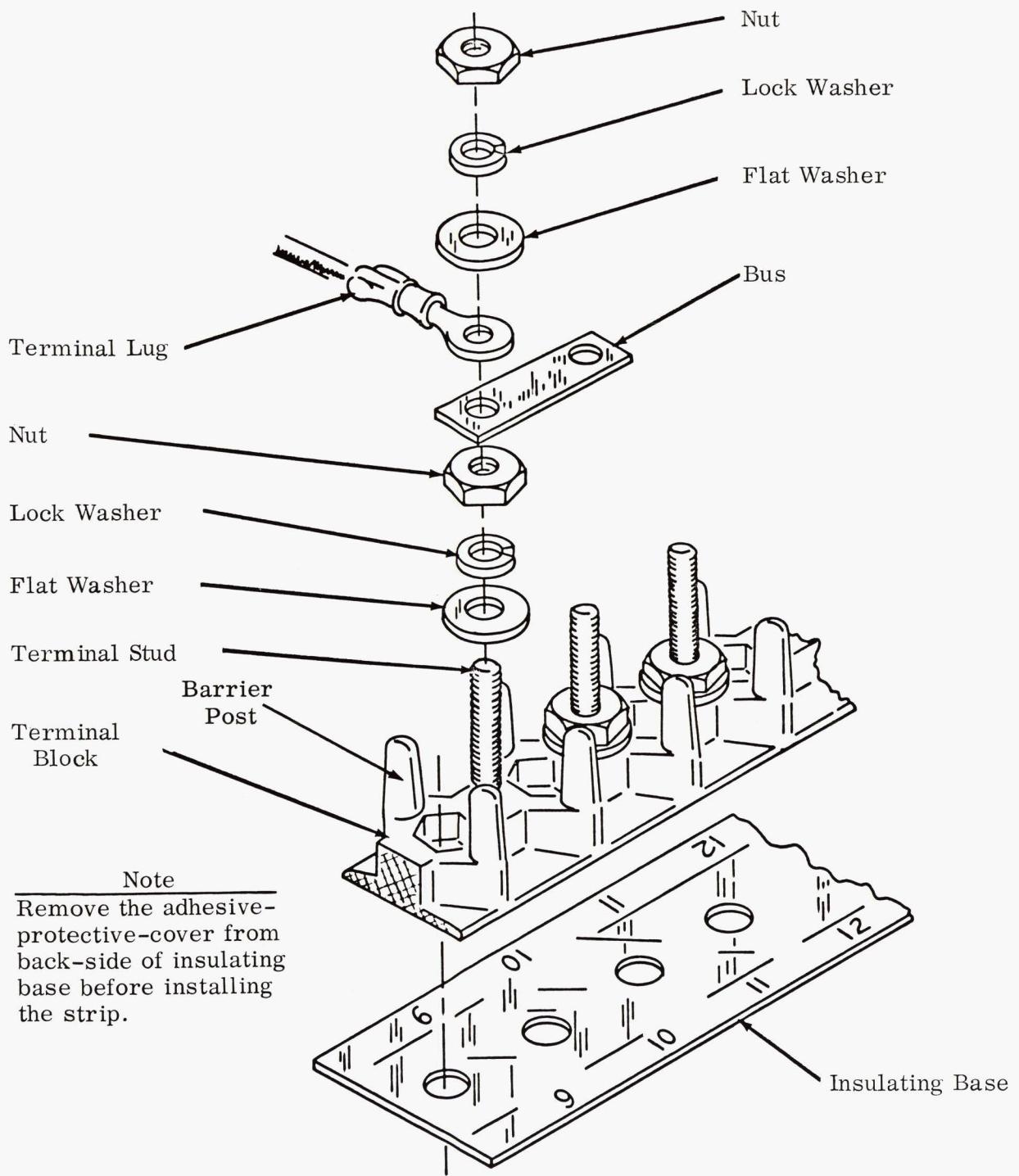


Figure 6-3. Terminal Block Assembly (High Temperature) Shown With Complete Complement of Hardware for One Terminal Stud

1. Terminal strips altered by increasing the mounting hole sizes or material removed from the strip in any manner.
- m. Terminal lug mounting hole deformed.
- n. Evidence of cracks or work hardening on terminal lugs.
- o. Evidence that terminal lugs bent for wire training were rebent or straightened.
- p. Evidence of lacquer, paint, primer, or any other foreign matter on contact areas of terminal lugs, bus bars, structure, and terminal studs.

## 6.3 SEALED TERMINAL STRIP ASSEMBLIES

### 6.3.1 WIRES WITH CRIMPED CONTACTS

Crimped pin contacts which are affixed to wires for use in sealed terminal strip assemblies shall be inspected as follows.

#### 6.3.1.1 Wire Preparation

Prior to crimping the contacts on wires, inspection will verify the following:

- a. Insulation has been etched in accordance with the requirements outlined in Section 10.
- b. Wires have been stripped in accordance with the applicable process specification. (Refer to Figure 6-6.)
- c. The stripped portion of conductor is clean and has no missing, nicked, or damaged strands. (Refer to Figure 6-6.)
- d. The natural twist or "lay" of the strands in the conductor has not been disturbed; however, minor disturbances may be restored.

#### 6.3.1.2 Crimp Contact Preparation

Prior to crimping, inspection shall verify the following:

- a. Crimp contacts to be used are of the appropriate type and size as specified on the engineering drawing or wire list.
- b. Crimp contacts are not deformed.
- c. Plating is not damaged in any manner (corrosion, discoloration, peeling, etc).

#### **6.3.1.3 Crimping Tools**

Crimping shall be accomplished with calibrated crimping tools as specified in the applicable process specification. Refer to MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections, and to Section 13 for crimping tool certification and control requirements.

#### **6.3.1.4 Crimped Contact Inspection**

After crimping, contacts shall be inspected for the following characteristics:  
(Refer to Figure 6-6.)

- a. Wire must be visible through the inspection hole.
- b. Wire insulation shall not extend into the crimped portion of the contact barrel.
- c. The maximum insulation gap shall be equal to the outside diameter (over insulation) of the wire. Crimp pins which have an insulation barrel shall have no exposed conductor.
- d. Crimping indents shall be in the proper portion of the barrel.
- e. There shall be no cracks, splits, or flaked plating on crimped contacts.
- f. The contacts shall not be bent.

#### **6.3.1.5 Crimped Contact Insertion**

After the contact has been properly crimped and inspected, it shall be inserted in the sealed terminal strip assembly using an approved insertion tool (Refer to Section 13 and to Figure 6-4) and in accordance with the applicable process specification.

### **6.3.2 INSTALLATION OF SEALED TERMINAL STRIP ASSEMBLIES**

Sealed terminal strip assemblies (Refer to Figure 6-4) shall be installed according to the applicable process specifications. The number one terminal or index shall be in the position shown on the installation drawing.

### 6.3.3 INSPECTION

#### 6.3.3.1 Visual

The following conditions shall be cause for rejection:

- a. Wiring, extending from a sealed terminal strip, bent within 1/2 inch from the seal.
- b. Deformed seal around any entry hole.
- c. Tight wires causing a pull on the rubber seal.
- d. Unfilled holes in sealed terminal strips.

#### 6.3.3.2 Radiographic

Upon completion of pin installation and after visual inspection, sealed terminal strip assemblies shall be radiographed to assure proper seating of all terminal pins.

### 6.4 CRIMPED CONTACT CONNECTORS

Crimped contact connectors shall be assembled in accordance with applicable process specifications. The inspection criteria for crimp contact assemblies shall be as specified in paragraphs 6.3.1.1 through 6.3.1.4. After the contact has been properly crimped and inspected, it shall be inserted in the connector using an approved insertion tool (Refer to Section 13 and to Figure 6-5) and in accordance with the applicable process specification.

### 6.5 SOLDERED CONNECTIONS

Prior to acceptance, the quality of each soldered terminal connection shall be determined by visual inspection. A magnifying glass may be used to examine suspected defects. Reliable soldered electrical connections shall be clean and have a smooth appearance, no porosity, good fillet between conductor and terminal, good adherence of solder to terminal, and no excess solder. In all applications, except for solder cups, the contour of the wire or lead shall be visible after soldering, and the end of the wire or lead shall not extend beyond terminal dimensions. In solder cup applications, the contour of the wires and leads shall be visible from the insulation to the point of entry into the cup. Typical satisfactory and unsatisfactory soldered

connections are illustrated in Figures 6-7 through 6-11. Evidence of any defects, including but not limited to the following, shall be cause for rejection of a soldered connection.

- a. Charring, burning, or other damage to insulation.
- b. Splattering of flux or solder on adjacent connections or components.
- c. Solder points (peaks).
- d. Pits, scars, cracks, or holes.
- e. Excessive solder which obscures the connection configuration.
- f. Excessive wicking.
- g. Loose leads or wires.
- h. Cold solder connection.
- i. Rosin connection.
- j. Disturbed solder connection.
- k. Cut, nicked, stretched, or scraped leads or wires.
- l. Unclean connection (lint, residue, flux, solder splash, dirt, etc.).
- m. Dewetting.
- n. Insufficient solder.
- o. Visible bare copper or base metal.
- p. Clinched leads resulting in a reduction of the required spacing between conductors.

## 6.6 ELECTRICAL BONDING

Electrical assemblies require electrical bonding in accordance with the applicable engineering drawings and process specifications. Electrical bonding installations shall be inspected in accordance with the following criteria.

### 6.6.1 SURFACE PREPARATION

Prior to installation of bonding hardware, the mating surfaces shall be inspected for the following:

- a. All surface protective finish has been removed (in accordance with the applicable process specification) to bare metal in an area extending 1/8 to 1/4 inch beyond the circumference of the mating surfaces. Bare metal bonding contact surfaces of parts to be left unprotected more than 8 hours prior to bonding are to be protected with an approved removable protective coating.

- b. Mating surfaces have been cleaned with an approved solvent and are free of dirt, fingerprints, grease, oil, or smudges.
- c. Mating surfaces are free of dents, deep scratches, or other surface irregularities which would prevent intimate contact of all mating surfaces.

#### 6.6.2 BONDING INSTALLATION INSPECTION

The bonding installation shall be inspected for the following:

- a. Installation hardware is as specified by the applicable engineering drawing.
- b. Hardware (lugs, bolts, washers) is installed in the order and position specified on the applicable engineering drawing.
- c. Resistance measurements made between the bonded assembly and structure are in accordance with the applicable process specifications and within specified limits.
- d. Affected area has been treated and protective finish has been applied in accordance with applicable process specifications. Unprotected surfaces to be left untreated for longer than 72 hours shall have an approved removable protective finish applied in accordance with the applicable process specifications.

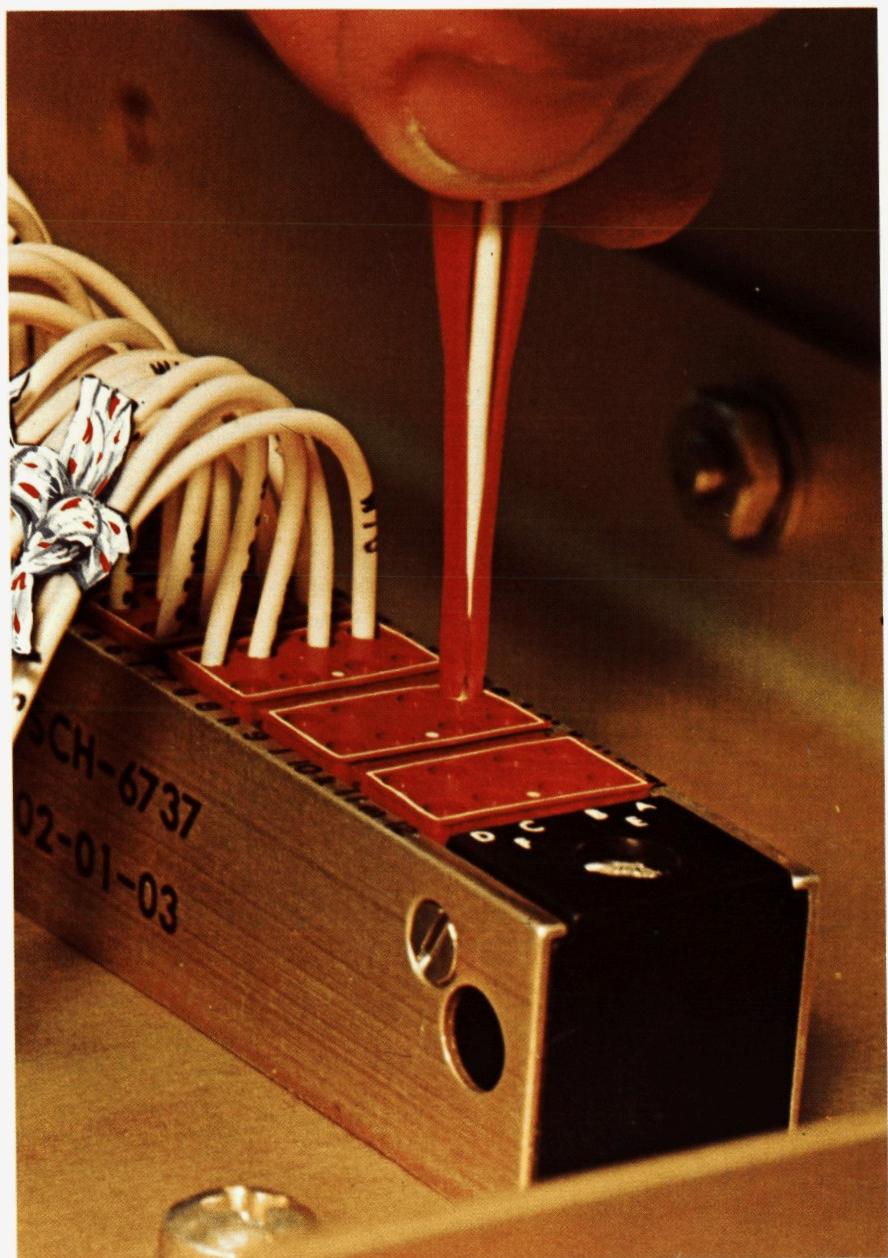


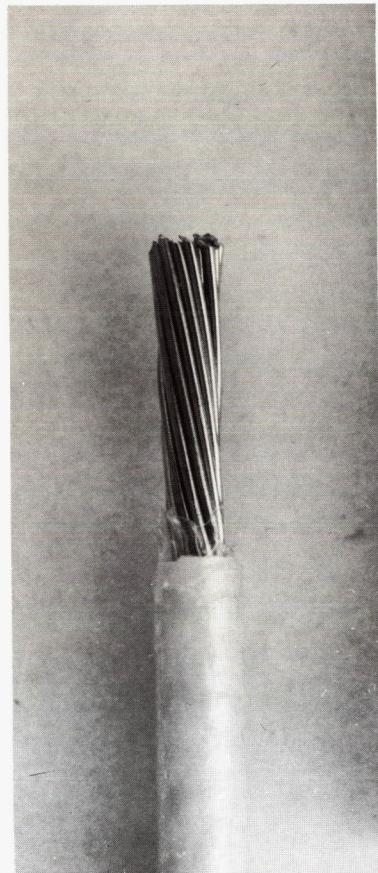
Figure 6-4. Insertion of a crimped contact into a sealed terminal strip assembly using an approved hand insertion tool.



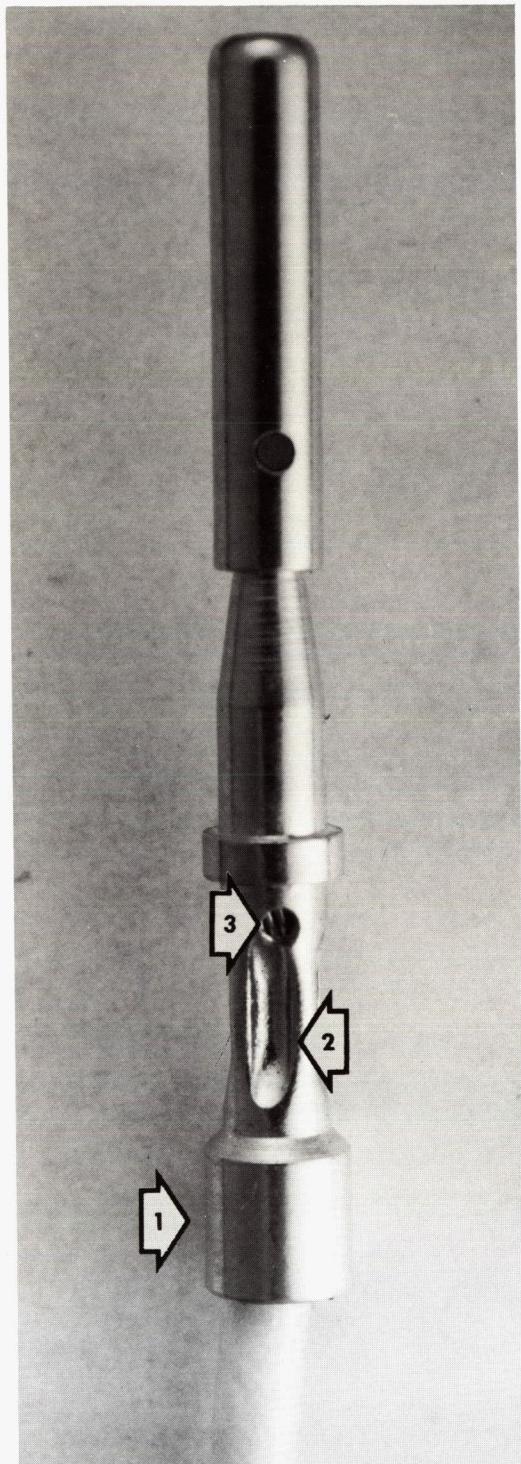
Figure 6-5. Insertion of crimped contact into a connector using an approved hand insertion tool.

Legend

- (1) Insulation Barrel
- (2) Crimping Tool Indentation (properly crimped)
- (3) Inspection Hole



a. Stripped Wire Before Insertion in Barrel

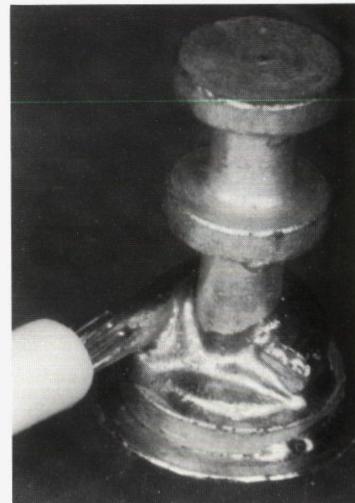


b. Elements for Inspection of Crimped Contact

Figure 6-6. Typical Example of Properly Crimped Contact



a. Insufficient



b. Minimum



c. Preferred

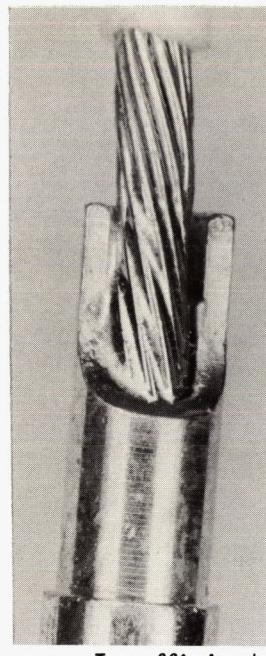


d. Maximum

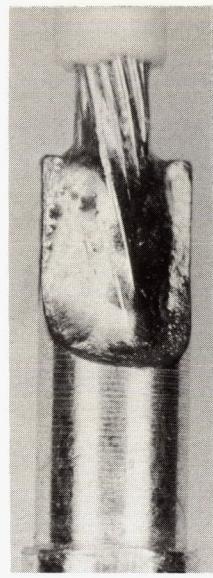


e. Excess

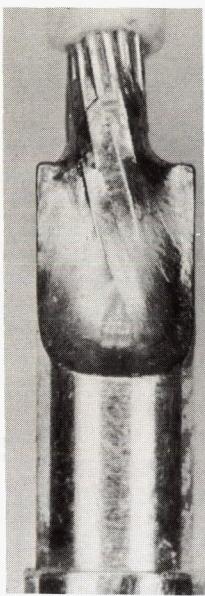
Figure 6-7. Soldered Connection Inspection Criteria



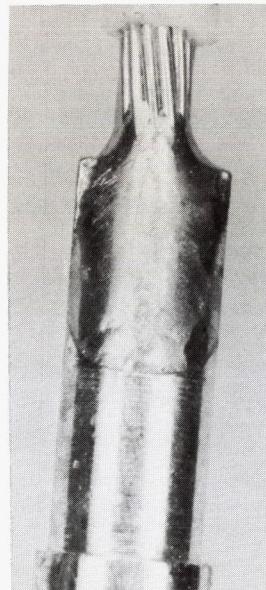
a. Insufficient



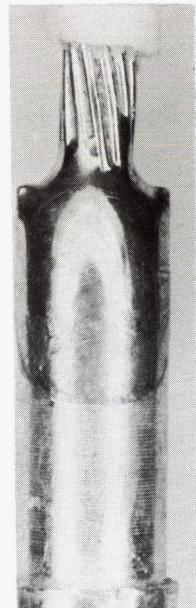
b. Minimum



c. Preferred



d. Maximum



e. Excess

Figure 6-8. Soldered Connection Inspection Criteria



a. Insufficient



b. Minimum



c. Preferred

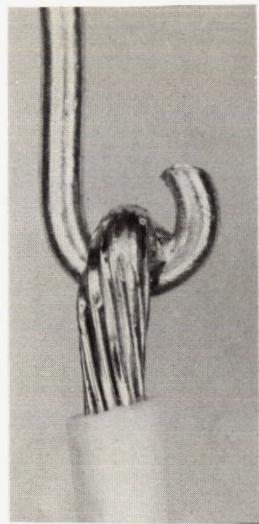


d. Maximum

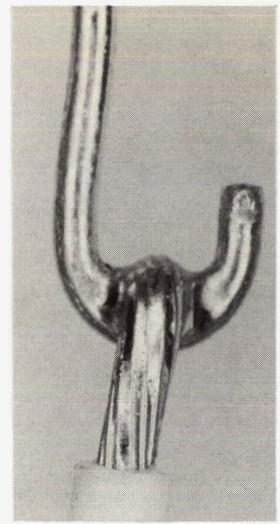


e. Excess

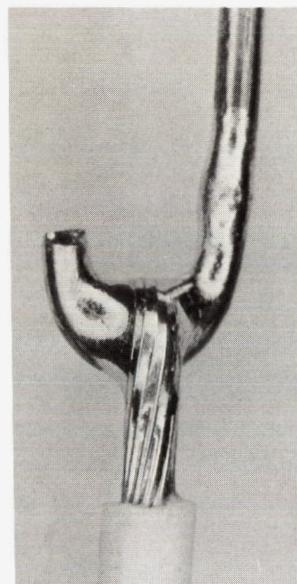
Figure 6-9. Soldered Connection Inspection Criteria



a. Insufficient



b. Minimum



c. Preferred

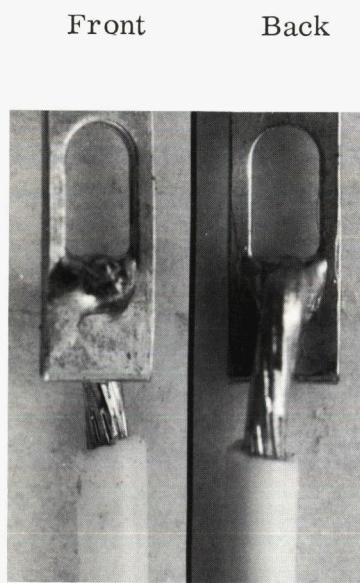


d. Maximum

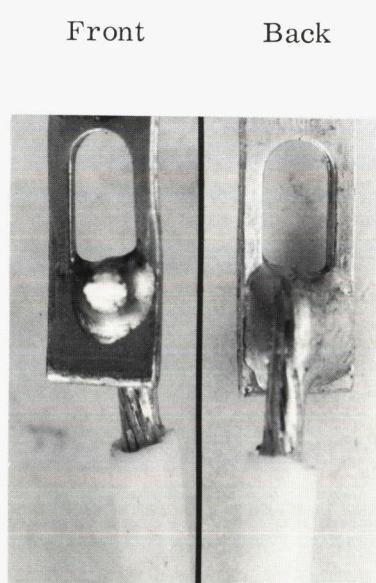


e. Excess

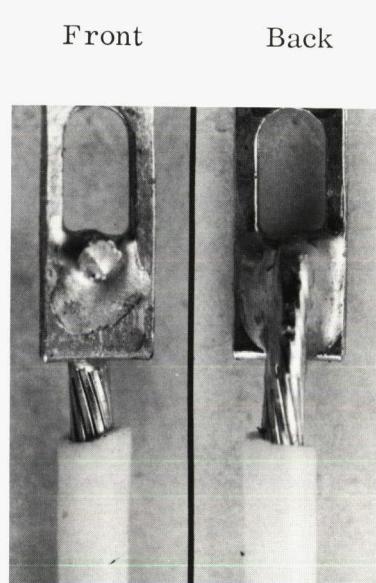
Figure 6-10. Soldered Connection Inspection Criteria



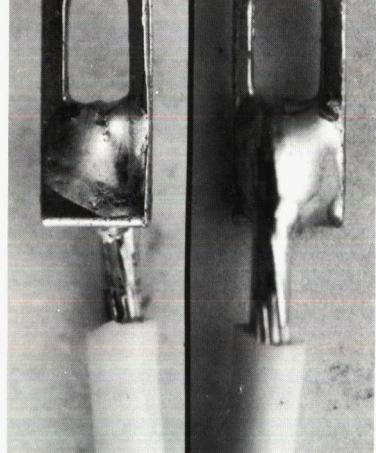
a. Insufficient



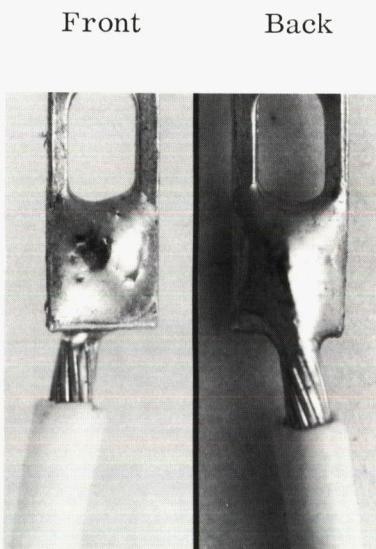
b. Minimum



c. Preferred



d. Maximum



e. Excess

Figure 6-11. Soldered Connection Inspection Criteria

## SECTION 7

### PRINTED CIRCUIT AND TERMINAL BOARD ASSEMBLIES

#### 7.1 GENERAL

This Section provides inspection criteria and standards for the inspection of terminal boards, printed circuit boards, and components prior to and after assembly. These criteria and standards are supplemental to the following documents referenced in paragraph 1.3.2:

- a. MSC-ASPO-S-5C, MSC-ASPO Soldering Specification
- b. MSC-ASPO-S-6A, MSC Supplement to NPC 200-4—June 1, 1966
- c. MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections

#### 7.2 PRELIMINARY PROCESS REQUIREMENTS

##### 7.2.1 ARTWORK

Master patterns that are utilized for the manufacture of printed circuit boards shall be examined by inspection personnel to ensure that the requirements of the applicable engineering drawings, specifications, and electrical schematics are satisfied.

##### 7.2.2 PHOTOGRAPHIC PROCESSES

Both positive and negative photographic reductions of original artwork shall be examined by inspection personnel. The presence of the following will be cause for rejection:

- a. Pin holes in conductor patterns.
- b. Irregular or ragged conductor patterns. (Refer to Figure 7-1.)
- c. Improper registration. (Refer to Figure 7-2.)
- d. Conductor line width, spacing, and terminal areas degenerated.
- e. Improper dimensions.

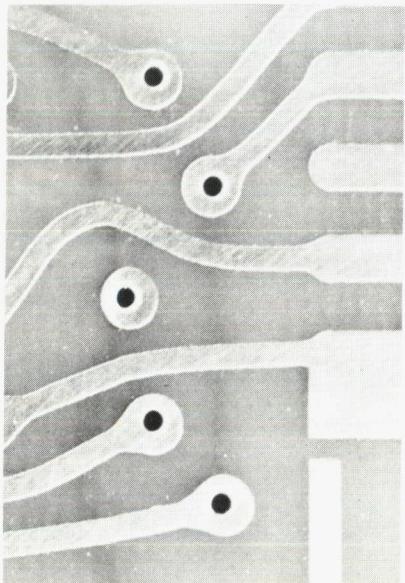
##### 7.2.3 COMPONENT PARTS

The presence of the following will be cause for rejection:

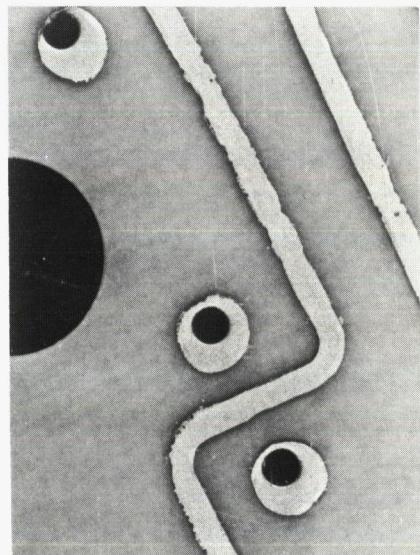
- a. Components do not meet design specification.
- b. Plating penetrated, base metal exposed. (Refer to Figure 7-3b.)

- c. Bend at seal of component body. (Refer to Figure 7-3f.)
- d. Exposed elements. (Refer to Figure 7-4.)
- e. Chips, pin holes in component body. (Refer to Figure 7-4.)
- f. Component leads corroded and/or mutilated. (Refer to Figure 7-3e.)

Acceptable



Not Acceptable



- a. Conductor line edges are smooth and even.
- b. Conductor line edges are poorly defined. Also note the off-center hole locations.

Figure 7-1. Line Edge Definition and Hole Locations

#### 7.2.4 MOUNTING BOARDS

Before component mounting, printed circuit boards shall be inspected using the following criteria:

- a. The printed circuit board shall be free of all grease, dirt, tape, or foreign materials and contaminants.
- b. Printed circuit board conductors and solder paths shall be tin - lead coated.
- c. When gold plating is required in special applications, all gold shall be removed from the pad areas prior to soldering. (Refer to paragraph 13.6.3.3 and Figure 7-5.)

Registration is the degree of alignment of conductor pattern with intended location on the printed wiring board, or to another pattern on the opposite side of base material.

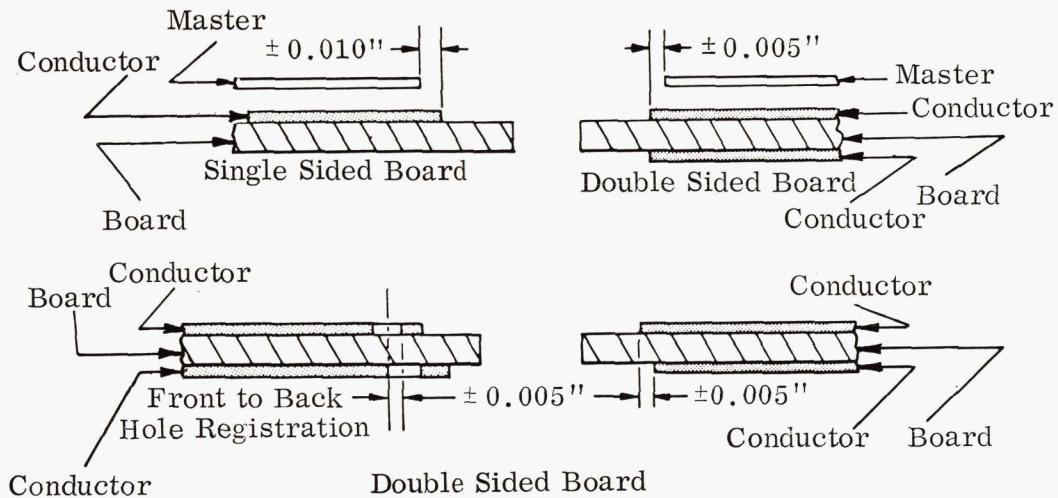
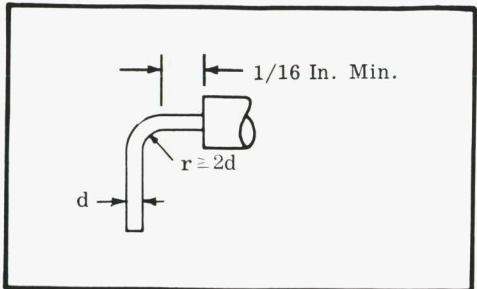


Figure 7-2. Acceptable Area Registrations

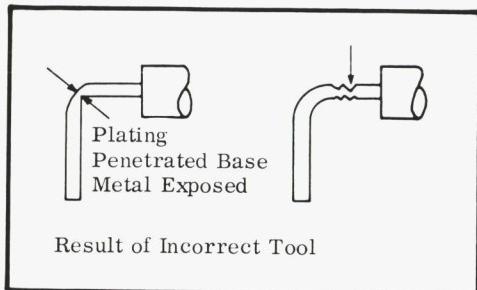
### 7.3 COMPLETED BOARDS

The completed printed circuit boards shall be submitted for inspection. The presence of the following shall be cause for rejection:

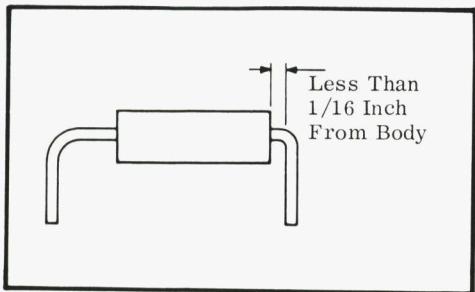
- a. Platings or coatings which are rough, show evidence of corrosion, flaking, deweeting, or contamination. (Refer to Figure 7-6.)
- b. Base materials which exhibit delamination.
- c. Pits, cuts, scratches, or undercutting which reduces conductor cross-sectional area by more than 20 percent. (Refer to Figure 7-7.)
- d. Copper or plating materials existing in noncircuit areas. (Refer to Figure 7-8.)
- e. Less than 0.010 inch of pad material located around the component lead holes of 0.030-inch diameter or smaller; less than 0.015 inch of pad material located around the component lead holes greater than 0.030-inch diameter. (Refer to Figure 7-1.)
- f. Front-to-back registration errors which exceed 0.005 inch. (Refer to Figure 7-2.)



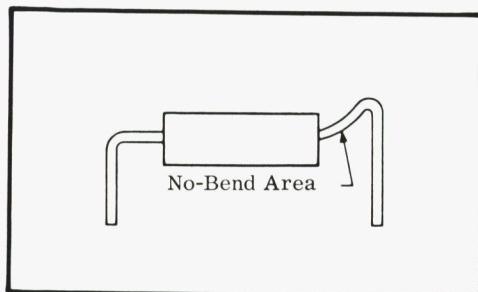
a. Acceptable



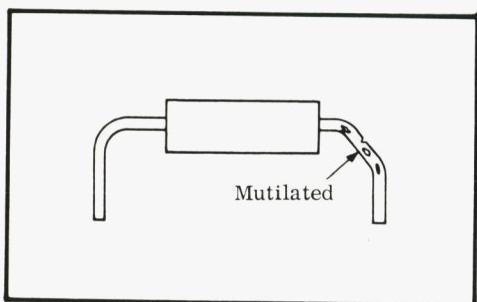
b. Not Acceptable



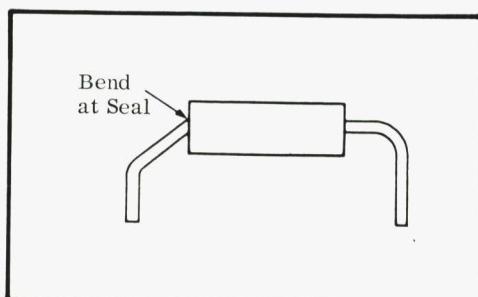
c. Not Acceptable



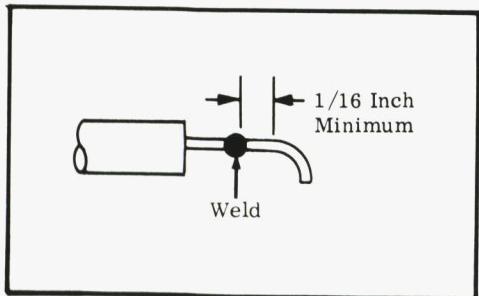
d. Not Acceptable



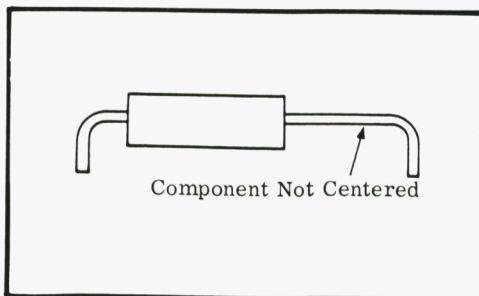
e. Not Acceptable



f. Not Acceptable



g. Acceptable



h. Not Acceptable

Figure 7-3. Component Bends

#### 7.4 TERMINAL BOARDS

Terminal board assemblies shall be examined by inspection personnel to assure compliance with process specifications. The following shall be cause for rejection:

- a. Terminals not properly seated on the board.
- b. Improper terminal length for board thickness.
- c. Bent terminals.
- d. Board damage due to improper swaging.
- e. Any split or damage in swaged portion of terminals.
- f. Damaged terminal plating.

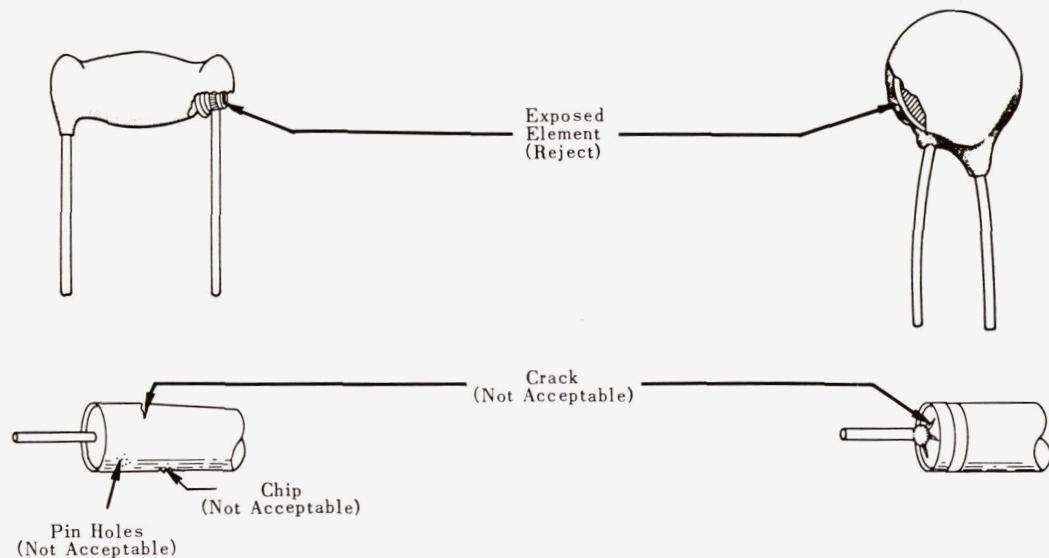


Figure 7-4. Component Body Conditions

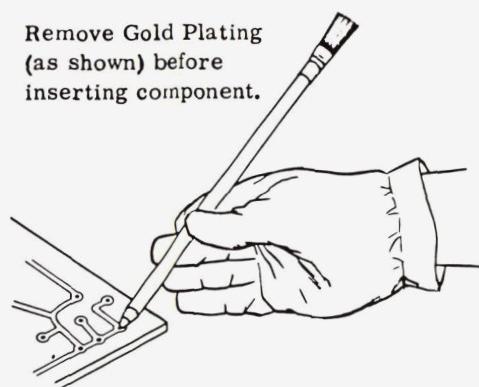
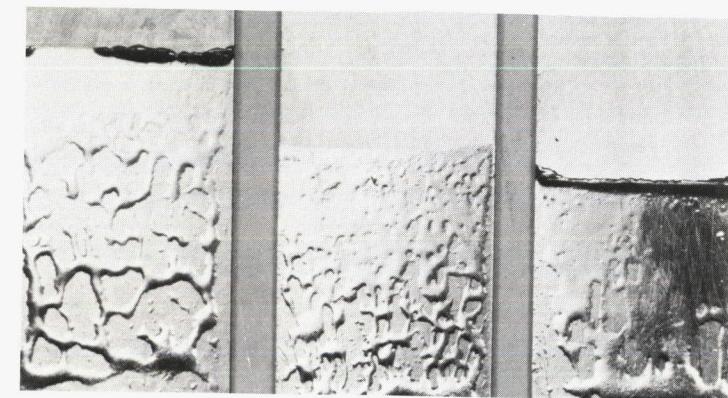
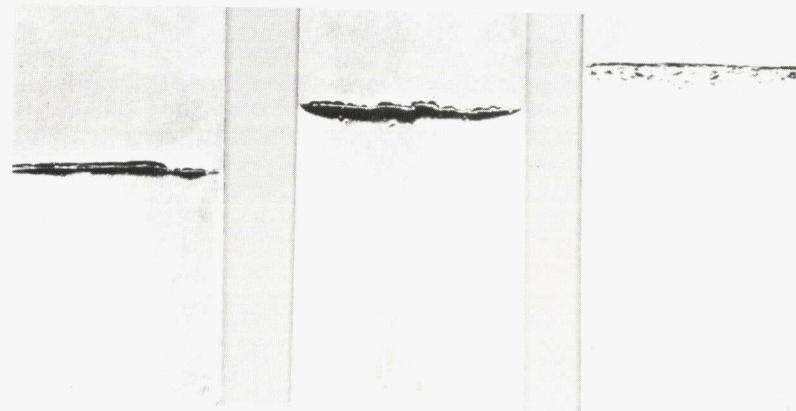
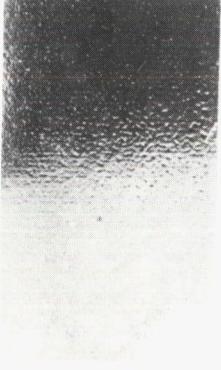


Figure 7-5. Abrasive Eraser to Remove Gold Plating

Preferred

Acceptable

Reject



- a. Several samples of smooth, bright, good wetted copper, and good solder coverage.
- b. Several samples showing minor dewetting areas. While minor dewetting shows, tests have proved that acceptable component soldering will be achieved.
- c. Several samples showing degrees of dewetting. These test panels would produce poor component soldering.

Figure 7-6. Solder-Coated Panels of Copper-Clad Laminate

Reject

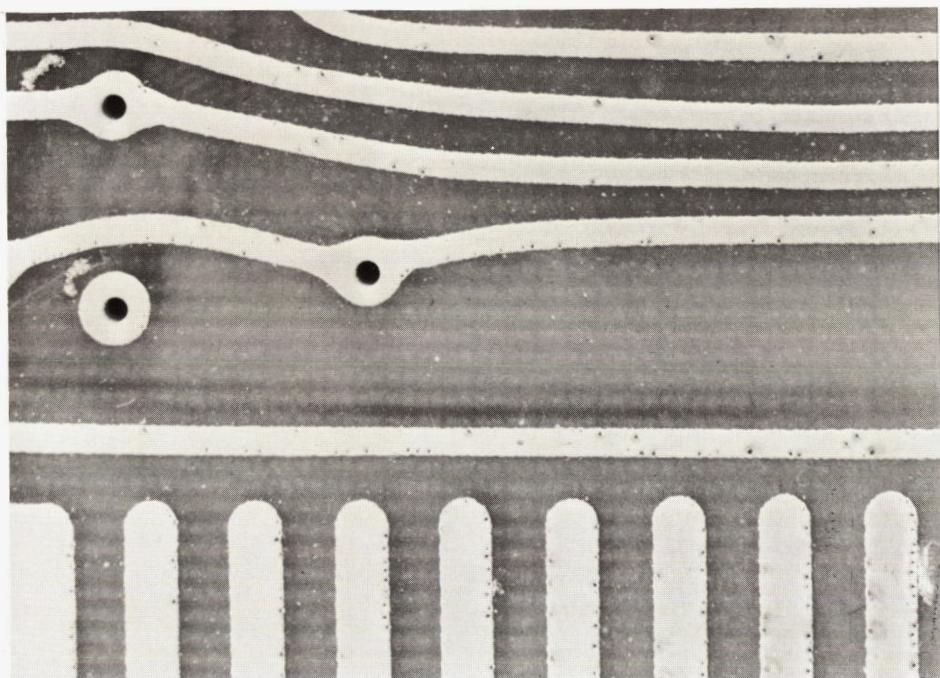


Figure 7-7. Severe Pitting of Plating

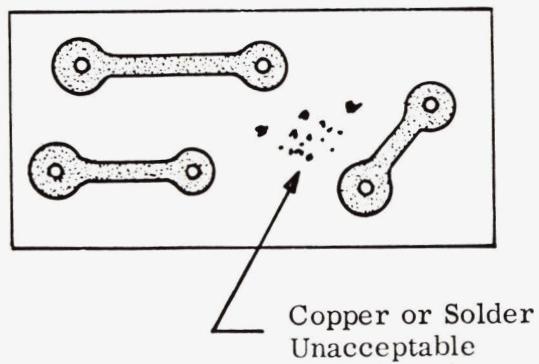


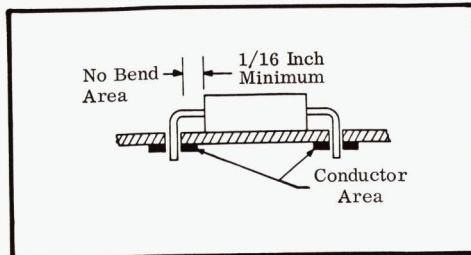
Figure 7-8. Copper or Solder in Noncircuit Area Unacceptable

## 7.5 BOARD ASSEMBLIES

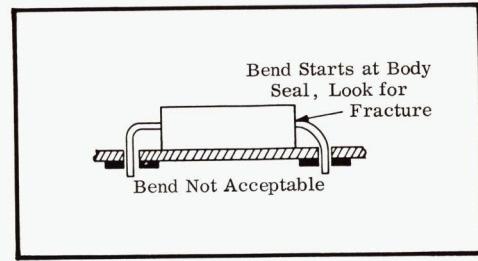
Board assemblies shall be examined by inspection personnel to assure compliance with process specifications.

Completed assemblies shall be inspected to assure that proper component mounting has been afforded. Absence of the following criteria shall be cause for rejection:

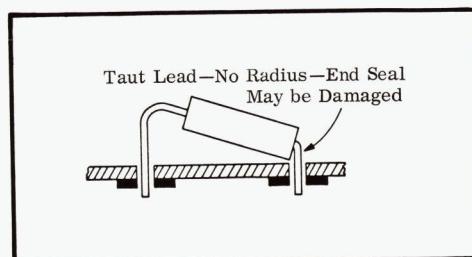
- a. Components shall be mounted parallel to and on the side opposite the printed circuitry and in contact with the printed circuit board unless otherwise specified by the design. (Refer to Figure 7-9.)
- b. The no-bend distance of component leads next to the component shall be 1/16 inch minimum. (Refer to Figure 7-9a, b, c, and d.)
- c. The vertical distance between flush mounted components and the printed circuit board shall be 1/32 inch maximum. (Refer to Figure 7-9e and f.)
- d. Direct contact between components is not acceptable. (Refer to Figure 7-9g.)
- e. The minimum unclinched lead shall be 1/32 inch; the maximum, 3/32 inch. (Refer to Figure 7-10.)
- f. Irregularly shaped components shall be potted, embedded or supported by a suitable method. (Refer to Figure 7-11.)
- g. Component leads and other conductors that are terminated directly at the circuit pad shall extend through the board a minimum of the pad radius (Refer to Figure 7-10b.) or a maximum of the pad diameter (Refer to Figure 7-10c.) and shall be clinched in the direction of, parallel to, and in contact with the circuit pattern. (Refer to Figure 7-10a.)
- h. All metal encased components that are mounted over printed wiring or in close proximity to other components shall be completely insulated with clear sleeving as is shown in Figure 7-12a.
- i. Prior to mounting and encapsulating glass encased components with epoxy potting material, the components shall be protected against thermal expansion by use of clear sleeving or other approved methods. (Refer to Figure 7-12b.)
- j. All components weighing 1/2 ounce or more shall be mounted by clamps or other means of support. (Refer to Figure 7-11.)



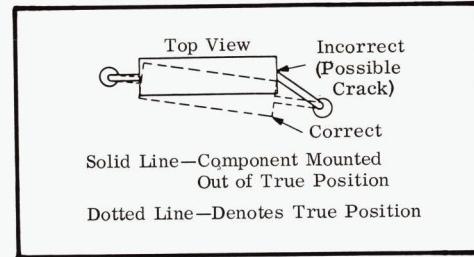
a. No-Bend Distance of Leads ACCEPTABLE



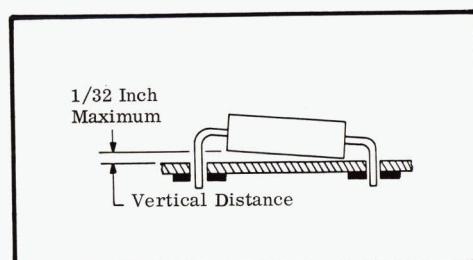
b. No-Bend Distance of Leads NOT ACCEPTABLE



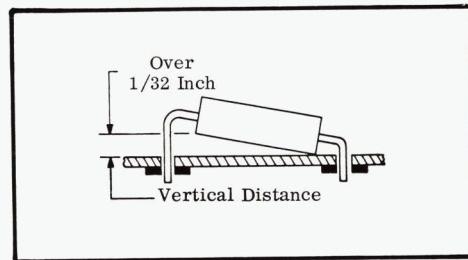
c. No-Bend Distance of Leads NOT ACCEPTABLE and Vertical Distance NOT ACCEPTABLE



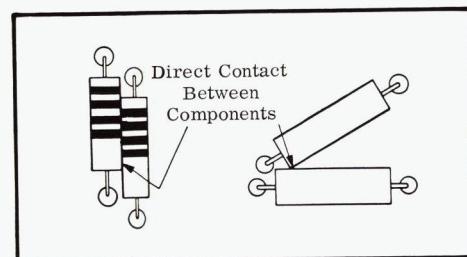
d. No-Bend Distance of Lead NOT ACCEPTABLE



e. Vertical Distance ACCEPTABLE

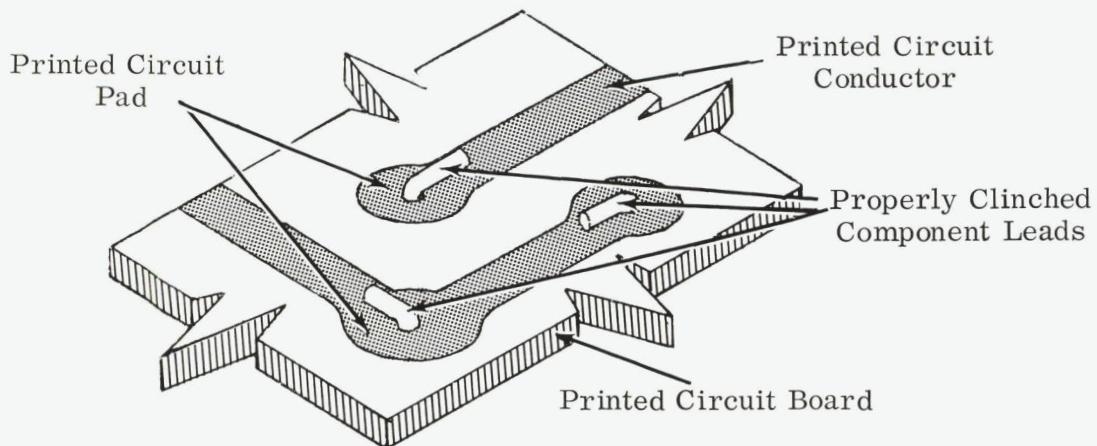


f. Vertical Distance NOT ACCEPTABLE

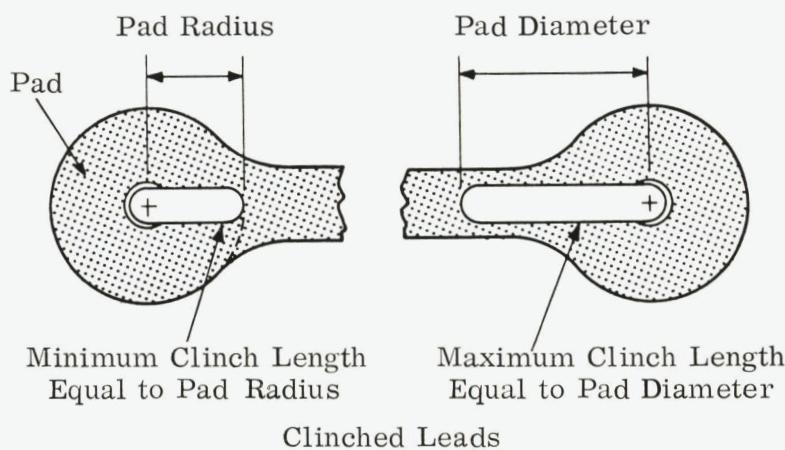


g. Component Contact NOT ACCEPTABLE

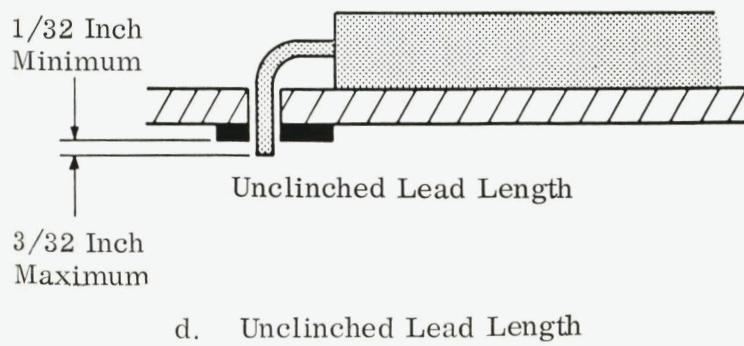
Figure 7-9. Component Mounting for Printed Circuit Boards



- a. Component leads clinched in direction of, parallel to, and in contact with circuit patterns.



- b. Minimum Clinch Length Equal to Pad Radius      c. Maximum Clinch Length Equal to Pad Diameter



- d. Unclinched Lead Length

Figure 7-10. Properly Clinched Component Leads on a Circuit Board

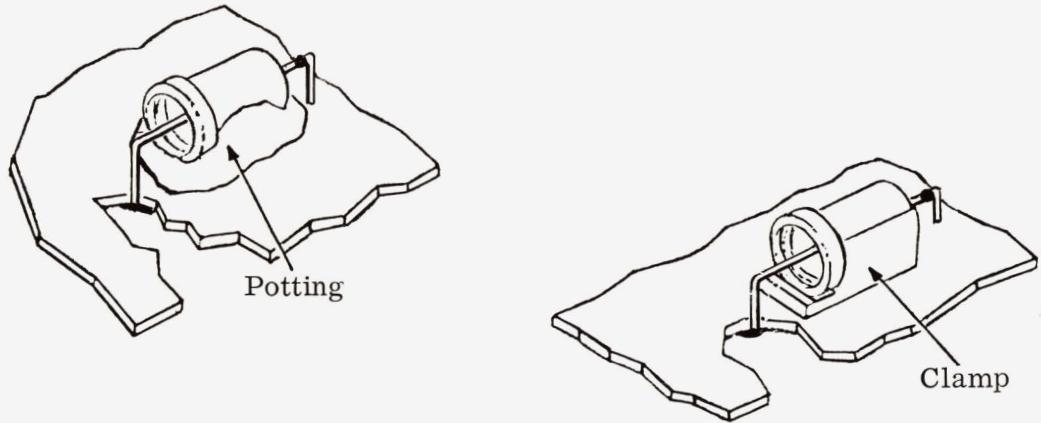


Figure 7-11. Irregularly shaped components shall be potted, embedded, or supported by a suitable method.

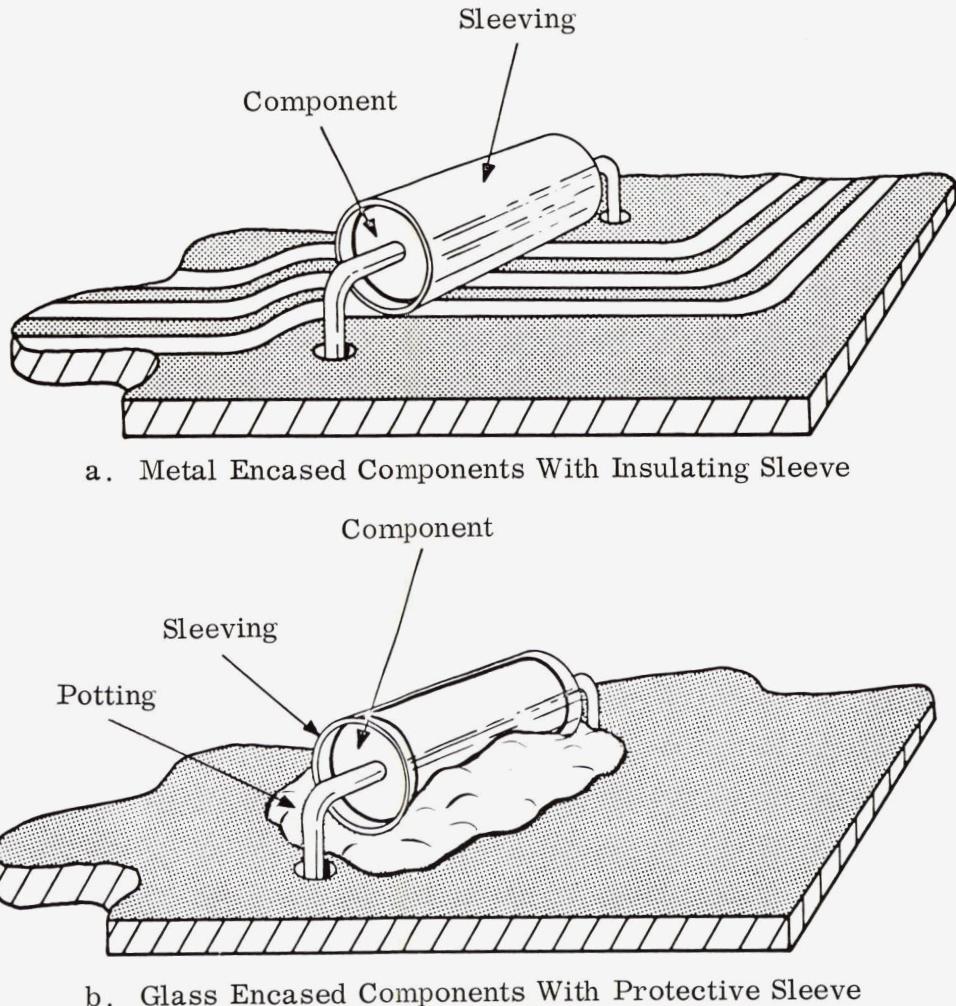


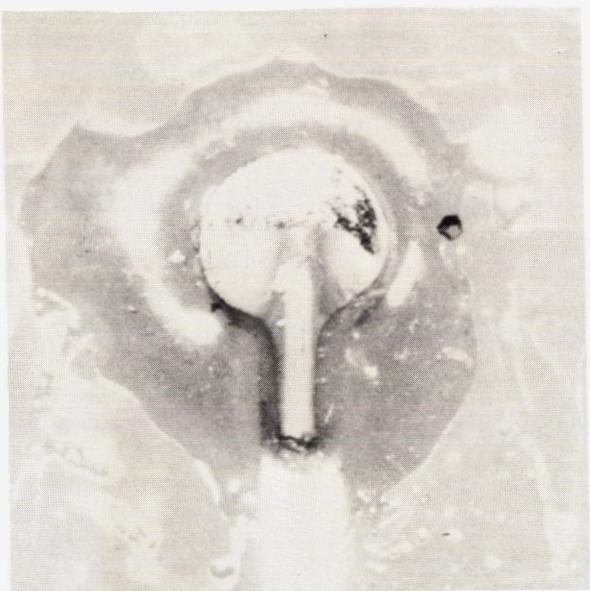
Figure 7-12. Encased Components on Printed Circuit Boards

- k. All components dissipating one watt or more of electrical power shall be mounted so that the body of the part is not in direct contact with the board unless thermal ground planes or clamps are used. These devices will dissipate sufficient heat so that the maximum board temperature is not exceeded.
- l. All components shall be mounted so that the values can be easily identified.

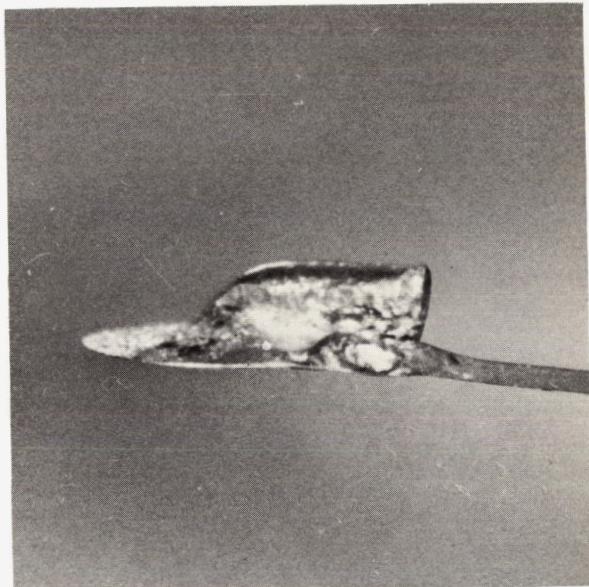
#### 7.6 COMPONENT CONNECTIONS

All printed circuit board electrical connections shall be examined to ensure they are acceptable. Electrical connections that evidence any defects including, but not limited to the following, shall be cause for rejection. Typical unsatisfactory electrical connections are as illustrated in Figures 7-13, 7-14, and 7-15.

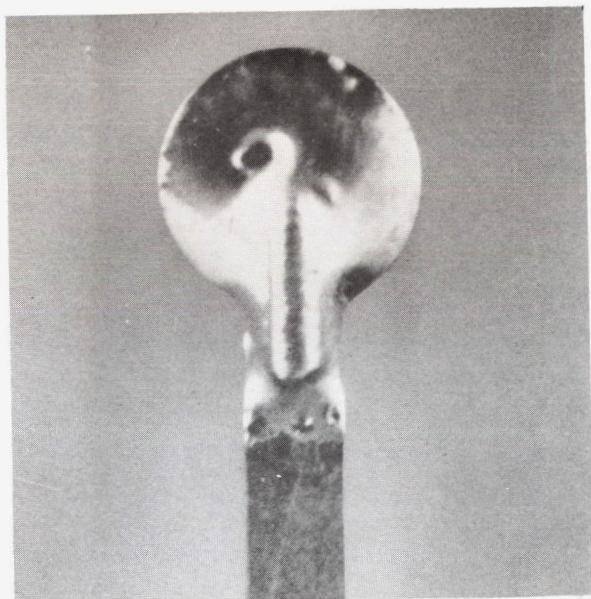
- a. Improper lead bend or stress relief.
- b. Pitted connection.
- c. Fractured connection.
- d. Circuit pattern delamination.
- e. Dewetted connections.
- f. Splattering of flux or solder on adjacent connections or components.
- g. Solder points (peaks).
- h. Excessive solder (outline of conductor not visible).
- i. Loose leads or wires.
- j. Cold solder connection.
- k. Disturbed solder connection.
- l. Rosin connection.
- m. Insufficient solder.
- n. Visible bare copper or base metal.
- o. Lead clinch insufficient or clinched leads resulting in a reduction of the required spacing between conductors.
- p. Charring, burning, wicking, or other damage to conductor wire, insulation, or printed circuit base material.



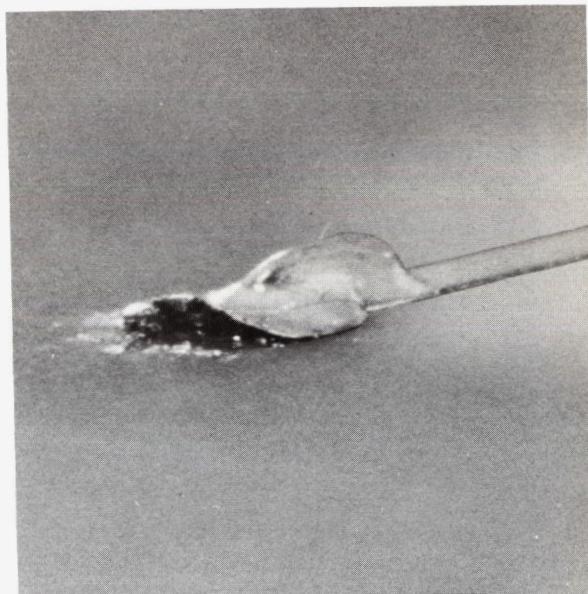
a. Improperly Cleaned



b. Fractured



c. Pitted



d. Circuit Pattern Delaminated

Figure 7-13. Unacceptable Connections on Printed Circuit Boards



a. Excessive Solder  
(Note Convex Appearance)



b. Overheated

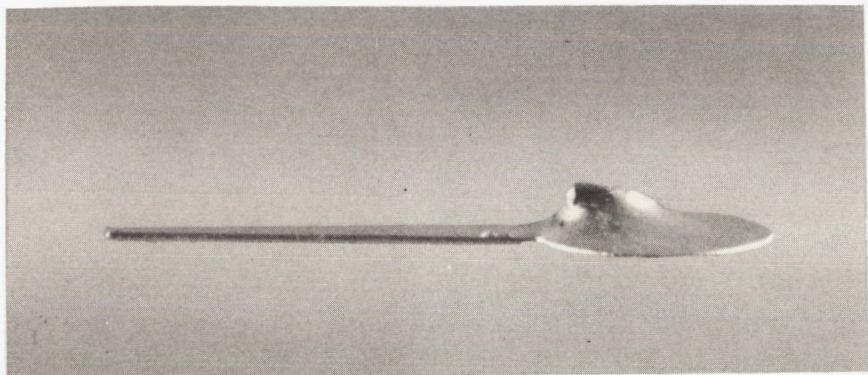


c. Insufficient Solder

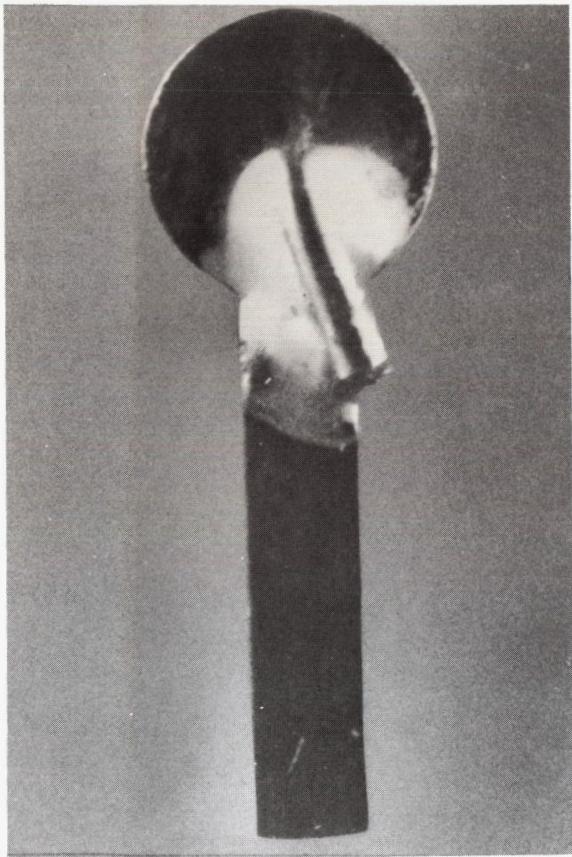


d. Dewetted

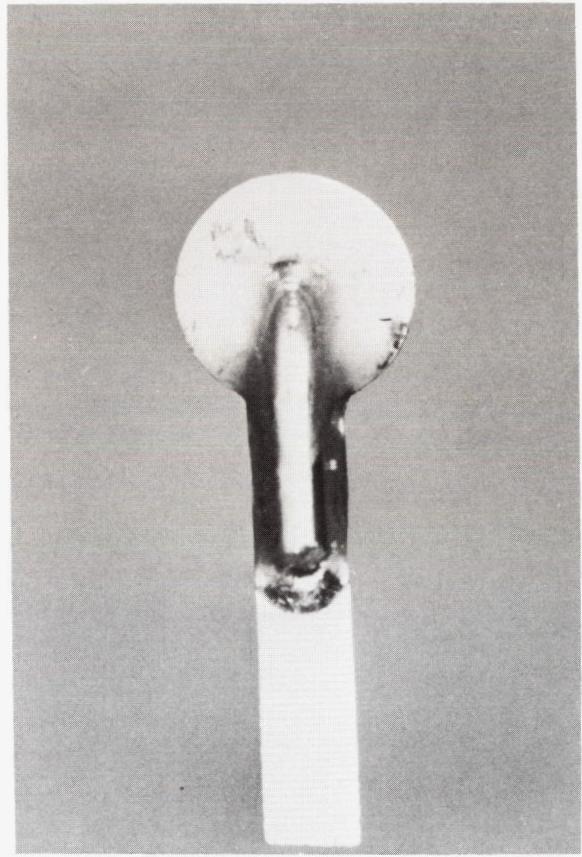
Figure 7-14. Unacceptable Connections on Printed Circuit Boards



a. Insufficient Lead Length



b. Out-of-Line With Circuit Pattern



c. Excessive Lead Length

Figure 7-15. Unacceptable Connections on Printed Circuit Boards

## SECTION 8

### SPLICES AND SHIELD TERMINATIONS

#### 8.1 GENERAL

All methods that are used in fabricating wire splices and shield terminations shall be in accordance with applicable standards and specifications. The following paragraphs point out some of the specific inspection criteria that shall be used in accepting or rejecting such items. These criteria and standards are to be supplemental to the following document referenced in paragraph 1.3.2:

MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections

#### 8.2 REQUIREMENTS

All splices or shield terminations that are installed in the spacecraft shall be recorded in a spacecraft log book or wire list. This log must at all times remain updated in order to determine the number and location of splices that are installed in any given wire and circuit. (A wire in this case is defined as one that is installed between two consecutive connectors. A circuit is defined as a group of wires that complete a functional path.) In addition, splices which utilize either crimped or solder sleeve connections shall meet the following criteria pertaining to location, accessibility, wire slack, doubling back, multiple splices, and identification.

##### 8.2.1 LOCATION

The location of wire splices and shield terminations shall be in accordance with the applicable drawings, wire list, or log book; but the following criteria shall be used as a basis for acceptance or rejection:

- a. Splices and shield terminations shall be staggered in order to limit buildup of bundle diameter. (Refer to Figure 8-1.)
- b. Splices or shield terminations shall not be positioned in a wire bundle so that they occur under cable clamps.
- c. Splices or shield terminations shall not be installed in the cutting area of a guillotine or adjacent to shaped-charge explosive cutters.

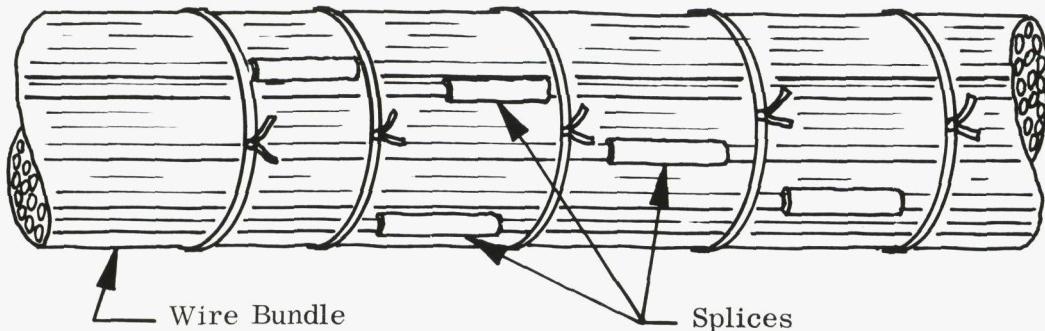


Figure 8-1. Method of Staggering Splices

#### 8.2.2 ACCESSIBILITY

Splices or shield terminations shall be accessible for inspection and shall be inspected before redressing and tying wires into the wire bundles.

#### 8.2.3 WIRE SLACK

Wire slack in the splice area shall not be permitted in excess of that necessary to facilitate the use of a crimping tool or a heat gun. Any slack that results during the installation of the splice shall be dressed into the wire bundle. (Refer to Section 4.)

#### 8.2.4 DOUBLING BACK

If a wire that is installed in a shield termination is doubled back over the termination, the minimum bend radius shall be four times the wire diameter. (Refer to Section 4.)

#### 8.2.5 MULTIPLE SPLICES

Multiple-wire splices (more than one wire in the end of a splice) shall be fabricated using only the gauge and quantities of wires as indicated in the process specification; however, violation of the following criteria shall be cause for rejection:

- a. From both ends of any splice, there shall be no more than a total of six wires.
- b. From one end of any splice, there shall be no more than a total of four wires.

### 8.2.6 IDENTIFICATION

Inspection shall ensure that outer insulation sleeves bear the identification of the splice or shield termination as specified on the applicable engineering drawing, wire list, or Material Review Board (MRB) document.

### 8.3 INSTALLATION OF CRIMPED SPLICES

Crimped splices shall only be used as specified on the applicable engineering drawing, wire list, or as approved by MRB action.

#### 8.3.1 WIRE PREPARATION

Prior to crimping splices on wiring, inspection shall verify the following:

- a. The wires have been stripped in accordance with the applicable process specification.
- b. The stripped portion of conductor is clean and has no missing, nicked, or damaged strands.
- c. The natural twist or "lay" of the strands in the conductor has not been disturbed; however, minor disturbances may be restored.

#### 8.3.2 CRIMP PREPARATION

Prior to crimping, inspection shall verify the following:

- a. Splices to be used are of the appropriate type and size as specified on the engineering drawing, wire list, or MRB document.
- b. Splices are not deformed or damaged in any manner.
- c. Plating is not damaged in any manner (corrosion, discoloration, peeling, etc.).

#### 8.3.3 CRIMPING TOOLS

Crimping shall be accomplished with calibrated crimping tools as specified in the applicable process specification. Refer to MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections, and to Section 13 for crimping tool certification and control requirements.

#### **8.3.4 CRIMPED SPLICE INSPECTION**

All crimped splices shall be inspected for the following characteristics:

- a. Crimp indentation shall be properly formed and located.
- b. There shall be no evidence of cracks, splits, or other damage to the splice.
- c. Conductor ends shall be at least flush with the end of the splice and shall not protrude more than 1/32 inch.
- d. The insulation of the wire shall not enter the splice; however, the maximum exposed portion of conductor shall not exceed 1/32 inch.

#### **8.3.5 OUTER SLEEVE INSTALLATION**

After completion of final inspection of the splice, an insulation sleeve shall be installed around the splice according to the criteria given in paragraph 8.6.

### **8.4 INSTALLATION OF SOLDER SLEEVE SPLICES**

Solder sleeve splices shall be used only as specified on the applicable engineering drawing, wire list, or MRB document; and shall be installed per the approved process specification. All phases of the installation shall be witnessed by inspection.

#### **8.4.1 WIRE PREPARATION**

Prior to installation of solder sleeve splice connectors on wires, inspection will verify the following:

- a. The wires have been stripped in accordance with the applicable process specification.
- b. The stripped portion of conductor is clean and has no missing, nicked, or damaged strands.
- c. The natural twist or "lay" of the strands in the conductor has not been disturbed; however, minor disturbances may be restored.

#### **8.4.2 SOLDER SLEEVE PREPARATION**

Prior to sleeve installation, inspection shall verify the following:

- a. Sleeves to be used are of the appropriate type and size as specified on the applicable engineering drawing, wire list, or MRB document.

- b. Heat shrinkable sleeve shows no evidence of damage (abrasion, nicks, cracks, etc.)
- c. Solder ring shows no evidence of deformation, corrosion, or discoloration.

#### 8.4.3 THERMAL HEAT GUNS

Thermal heat guns used for this installation shall be in accordance with paragraph 13.4 of this document.

#### 8.4.4 SOLDER SLEEVE SPLICE INSPECTION

All solder sleeve splices shall be inspected for the following characteristics (Refer to Figures 8-2 and 8-3.):

- a. Lay of conductors shall be parallel, and strands shall not be disturbed.
- b. There shall be no solder peaks or other sharp protrusions.
- c. Solder ring insert shall be completely melted.
- d. There shall be no indication of burning, blistering, scorching, discoloration, or other damage to the insulation of the spliced wire, insulation sleeve, or to adjacent wires.
- e. Contour of conductors and/or shields shall be visible through the sleeve and shall be well coated with solder.
- f. There shall be an acceptable fillet of solder between the conductors.
- g. The solder shall have an appearance that is smooth, bright, and undisturbed.

#### 8.4.5 OUTER INSULATION SLEEVE INSTALLATION

After inspection of the splice has been completed, an insulation sleeve shall be installed around the splice according to the criteria as given in paragraph 8.6.

### 8.5 SHIELD TERMINATIONS

Shield terminations shall be spliced as specified on the applicable engineering drawings, wire list, or MRB document.

#### 8.5.1 GENERAL

The following criteria shall apply to all shield terminations:

- a. The shield terminations shall be staggered in the wire bundle in a manner which will provide a minimum cable diameter buildup.
- b. All shielded ground wires shall be identified with the letters "SHLD GRD".
- c. The minimum length of shield ground wires shall be 2 inches. The maximum length shall be as required by the stagger requirements of paragraph 8.2.1 but shall not exceed 6 inches.
- d. Shielded ground wires formed by braiding or extending the shielding braid of a shielded cable in the form of pigtails shall not be used.
- e. When a shielded ground wire is to be connected to an electrical connector contact, the wire shall be the same size as the contact to which it is being connected. (Example, 20 gauge to 20 gauge; not 24 gauge to 20 gauge.)
- f. A jumper to a ground or a connector pin shall pick up no more than five shields.
- g. When a shielded cable terminates at a terminal board, the shielding braid shall be stripped back 1 inch to 6 inches from the end of the cable.
- h. When shields are to be terminated at potted connectors, the shielding braid shall be stripped back 1 inch to 4 inches from the back face of the potted area. Shield terminations shall not enter the potted area of electrical connectors.
- i. When shields are to be terminated at unpotted connectors, the shields shall be stripped back 1 inch to 3 inches as follows:
  - (1) On connectors with strain relief clamps, the measurement shall be from the back of the strain relief clamp.
  - (2) On connectors without strain relief clamps, the measurement shall be from the extreme back portion of the assembled connector.

#### 8.5.2 SHIELD GROUND WIRE PREPARATION

Prior to crimping ferrules, inspection shall verify the following:

- a. Wire to be used is of the appropriate type and gauge, as specified on the engineering drawing or wire list.

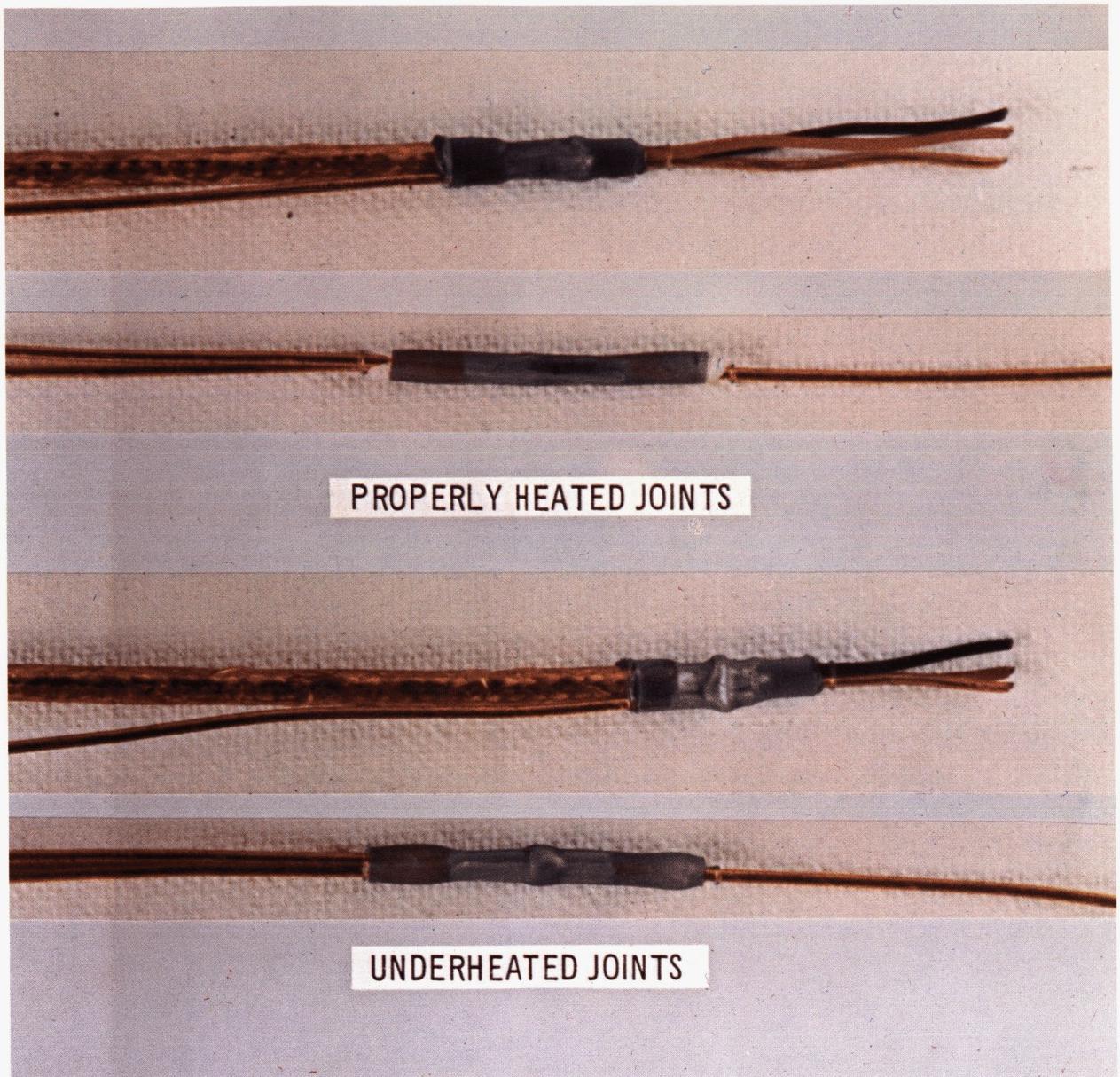


Figure 8-2. Solder Sleeve Splices

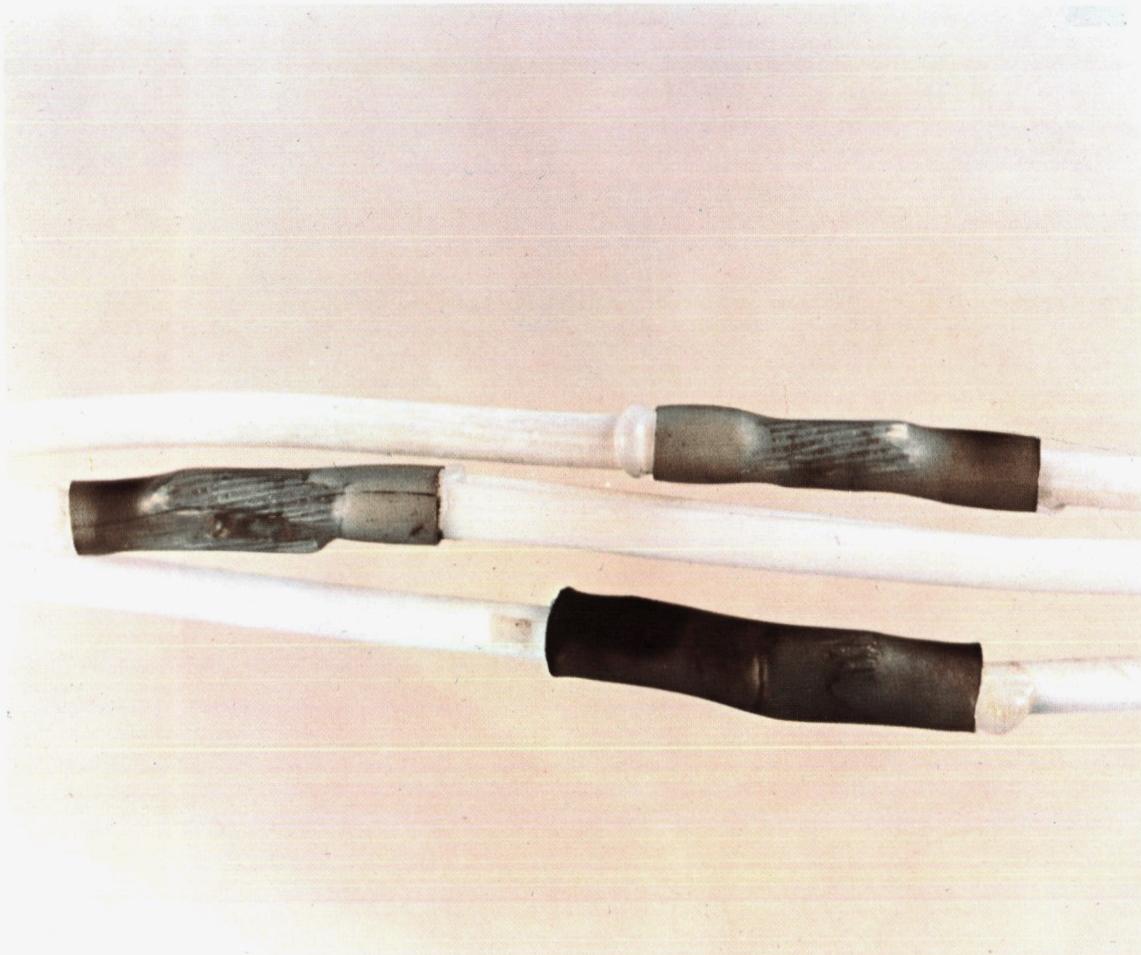


Figure 8-3. Examples of solder sleeves that are discolored through overheating. Outer insulation sleeves not installed.

- b. The wire has been stripped in accordance with the applicable process specification.
- c. The stripped portion of conductor is clean and has no missing, nicked, or damaged strands.
- d. The natural twist or "lay" of the strands in the conductor has not been disturbed; however, minor disturbances may be restored.

#### 8.5.3 SHIELD PREPARATION (Refer to Figures 8-4 and 8-5.)

Prior to crimping ferrules, inspection shall verify the following:

- a. The outer insulation has been stripped from the shield braid, and braid has been combed and trimmed in accordance with the applicable process specification.
- b. There are no protruding strands from the braid which could puncture conductor insulation.
- c. There are no more than three broken shield braid strands.

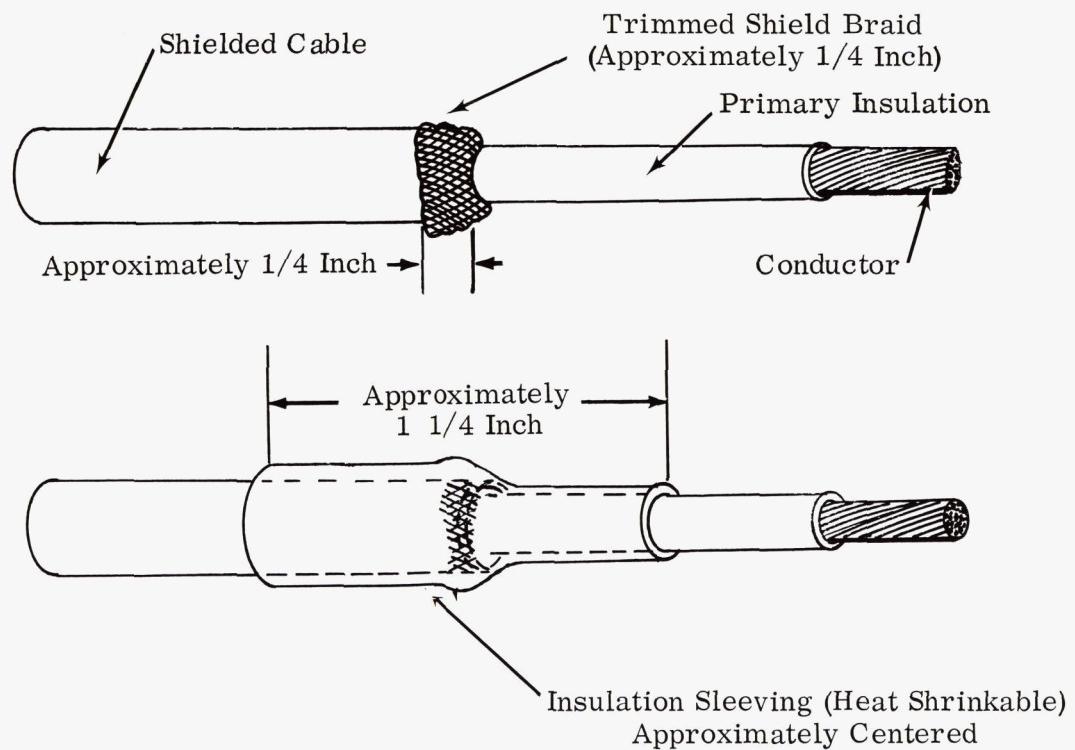
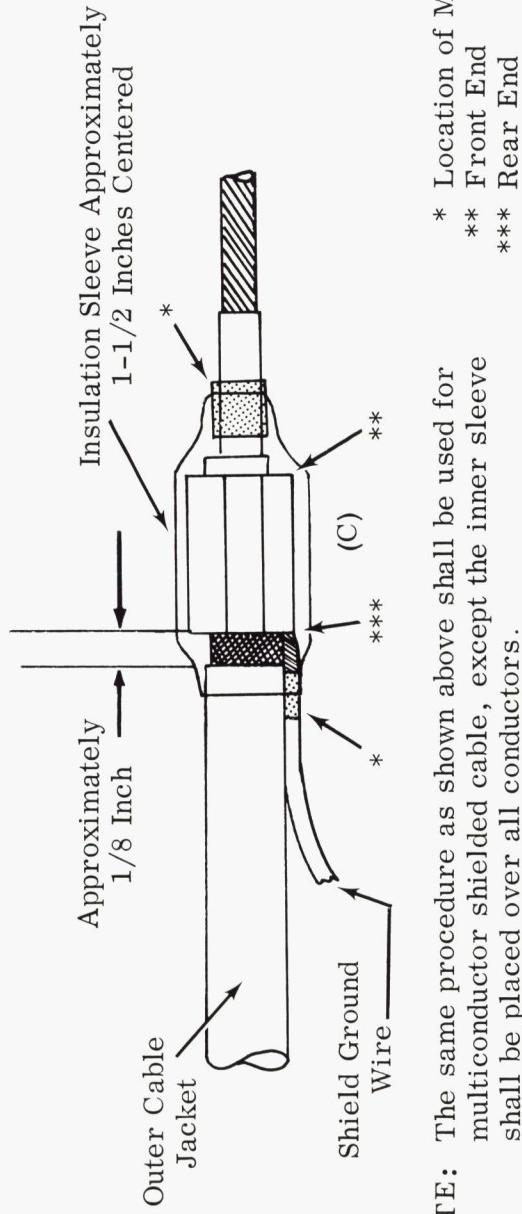
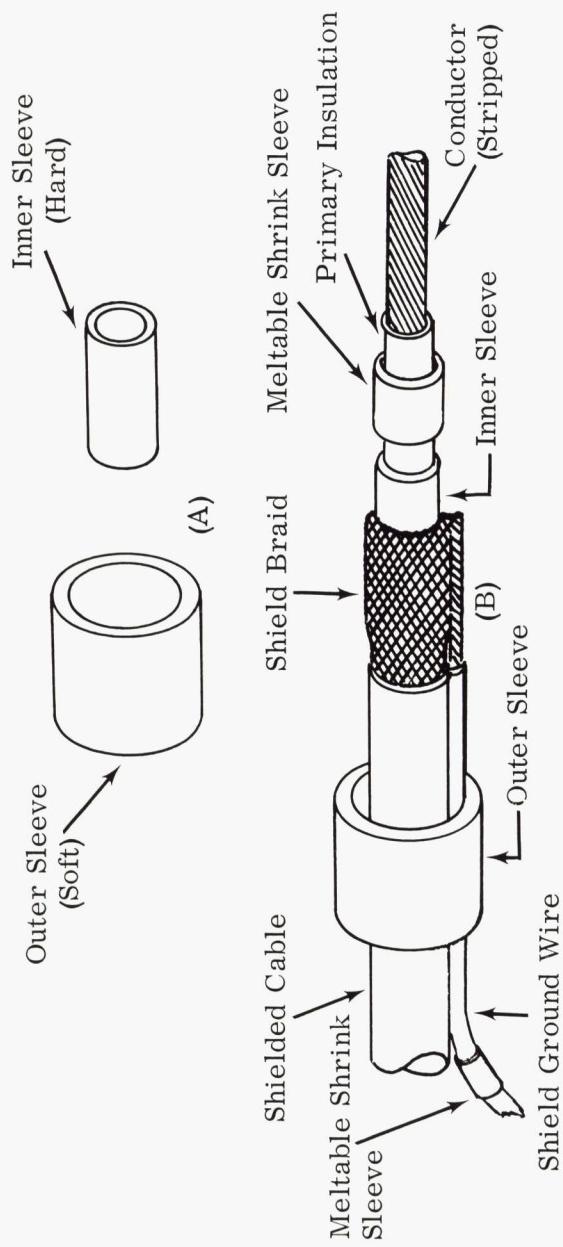


Figure 8-4. Termination of Ungrounded End of Shielded Cable



**NOTE:** The same procedure as shown above shall be used for multiconductor shielded cable, except the inner sleeve shall be placed over all conductors.

\* Location of Melted Sleeve  
\*\* Front End  
\*\*\* Rear End

Figure 8-5. Grounding Ferrule Installation

#### 8.5.4 FERRULE PREPARATION

Prior to crimping, inspection shall verify the following:

- a. Ferrules to be used are of the appropriate type and size as specified on the engineering drawing, wire list, or MRB document.
- b. Ferrules are not deformed or damaged in any manner.
- c. Ferrules show no evidence of corrosion, discoloration, etc.

#### 8.5.5 CRIMP CONNECTIONS

The correct size of tool for installing the various sizes of ferrule connections must be used to ensure proper compression of the grounding ferrule connections. Refer to MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections, and to Section 13 for crimping tool certification and control requirements.

#### 8.5.6 SOLDER SLEEVE CONNECTIONS

Solder sleeve connections shall comply with paragraph 8.4.

#### 8.5.7 INSPECTION OF SHIELD TERMINATIONS

When inspecting shield terminations, the following criteria shall apply:

- a. Jumpers shall be as short as possible, but of sufficient length for proper installation of grounding ferrules and termination of the conductors.
- b. The minimum bend radius of four times the wire diameter shall be maintained.
- c. The jumper wires shall be secured appropriately with spot ties.
- d. The shield terminations shall have no sharp edges or frayed shield ends that might damage conductor insulation.
- e. The shield terminations or shields shall have no appearance of shorting to center conductors of wires.
- f. For connecting two ungrounded cable shields, refer to Figure 8-6.
- g. For connecting three or more ungrounded cable shields, refer to Figure 8-7.
- h. Special attention must be given during the inspection of pyrotechnic connectors to ensure that shield terminations have been made in accordance with applicable specifications.

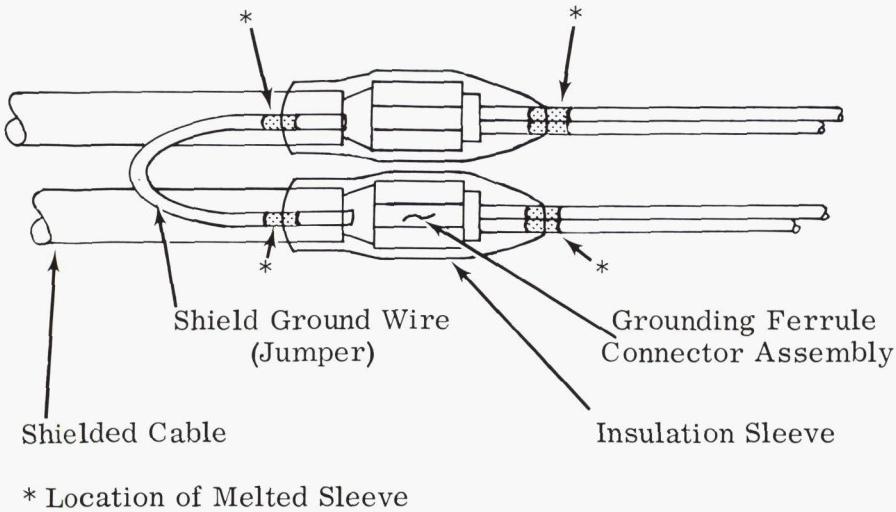


Figure 8-6. Termination of Ungrounded Ends of Two Cable Shields

#### 8.5.8 SPLICING OF SHIELDED CABLES

For splicing of shielded cables, the criteria for inspection is that covering the type of splice or shield termination being used. Coverage of crimped splices is in paragraph 8.3, solder sleeve splices in paragraph 8.4, and shield terminations in the above subparagraphs of 8.5. Figure 8-8 illustrates splicing of shielded cable without continuous shielding. Part D of Figure 8-9 illustrates application of shield splice with continuous shielding.

#### 8.5.9 INSULATION SHRINK SLEEVING (Refer to paragraph 8.6)

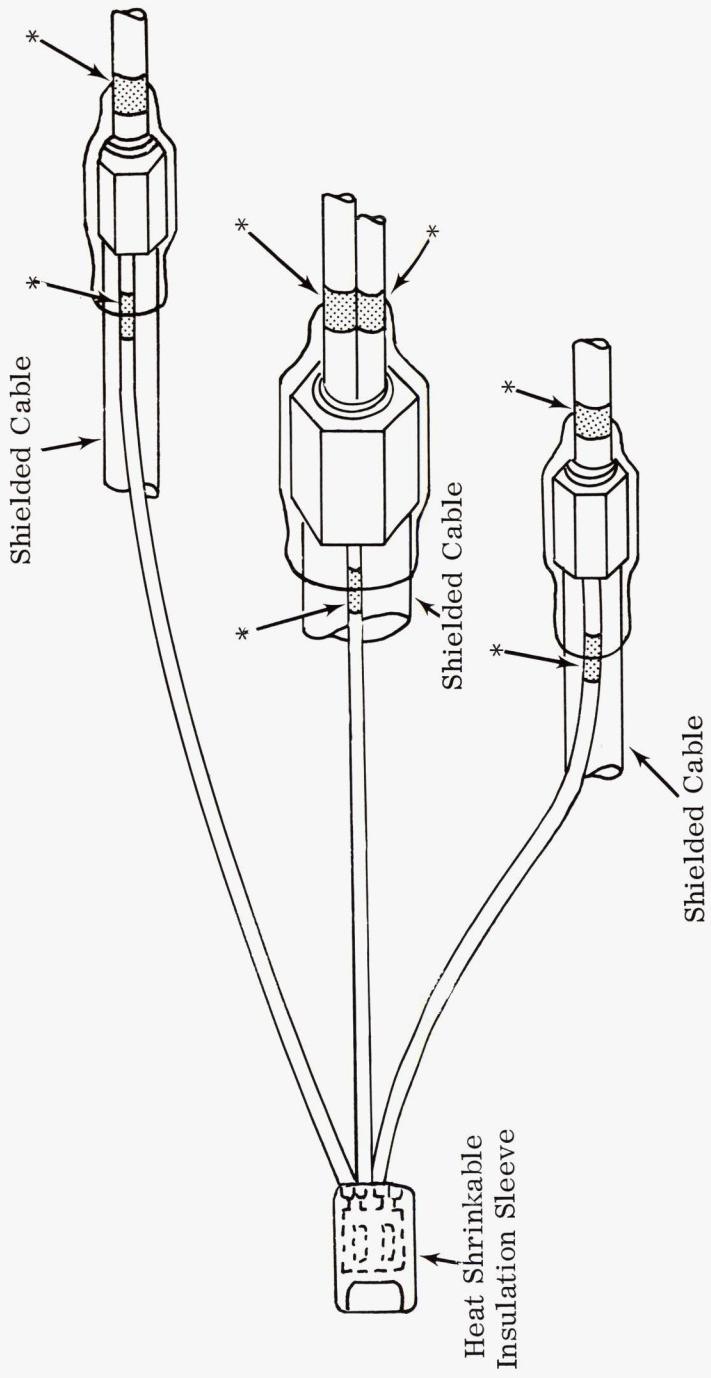
Insulation sleeving shall be used to:

- a. Cover a shielded ground ferrule installation including the area where the outer insulation jacket is stripped back. (Refer to Figure 8-5.)
- b. Cover uninsulated splices where they have been used to splice shielded cables or terminate shield ground wires. (Refer to Figures 8-6 through 8-10.)
- c. Cover the ungrounded end of a cable shield. (Refer to Figure 8-4.)

#### 8.6 INSULATION SLEEVES (HEAT SHRINKABLE)

Insulation sleeves shall be installed over splices, shield terminations, or ungrounded ends of cable shields and shall be inspected for the following:

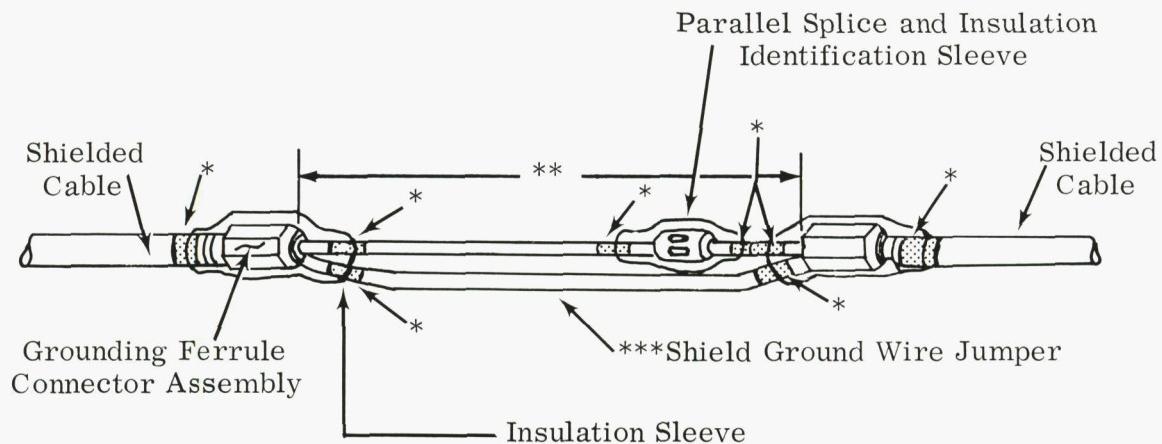
- a. Ensure that the sleeve is tight on the wire and that it follows the contour of the splice (Refer to Figures 8-2 through 8-11.)



\*Location of Melted Sleeves

Figure 8-7. An Ungrounded Common Shield Termination Point of Three Wires

- b. Ensure that the exterior surface of the sleeve is free from splits or cracks and that there is no evidence of overheating such as scorched, burned, or discolored sleeves and/or wire insulation. (Refer to Figure 8-3.)
- c. Ensure that the shrink sleeving contour is uniform and follows the outline of the component to form a tight seal. (Refer to Figure 8-2.)
- d. Ensure that all sleeves extend at least 1/2 inch past each end of the splices or terminations. (Refer to Figures 8-9 and 8-11.)



\* Locations of Melted Sleeves

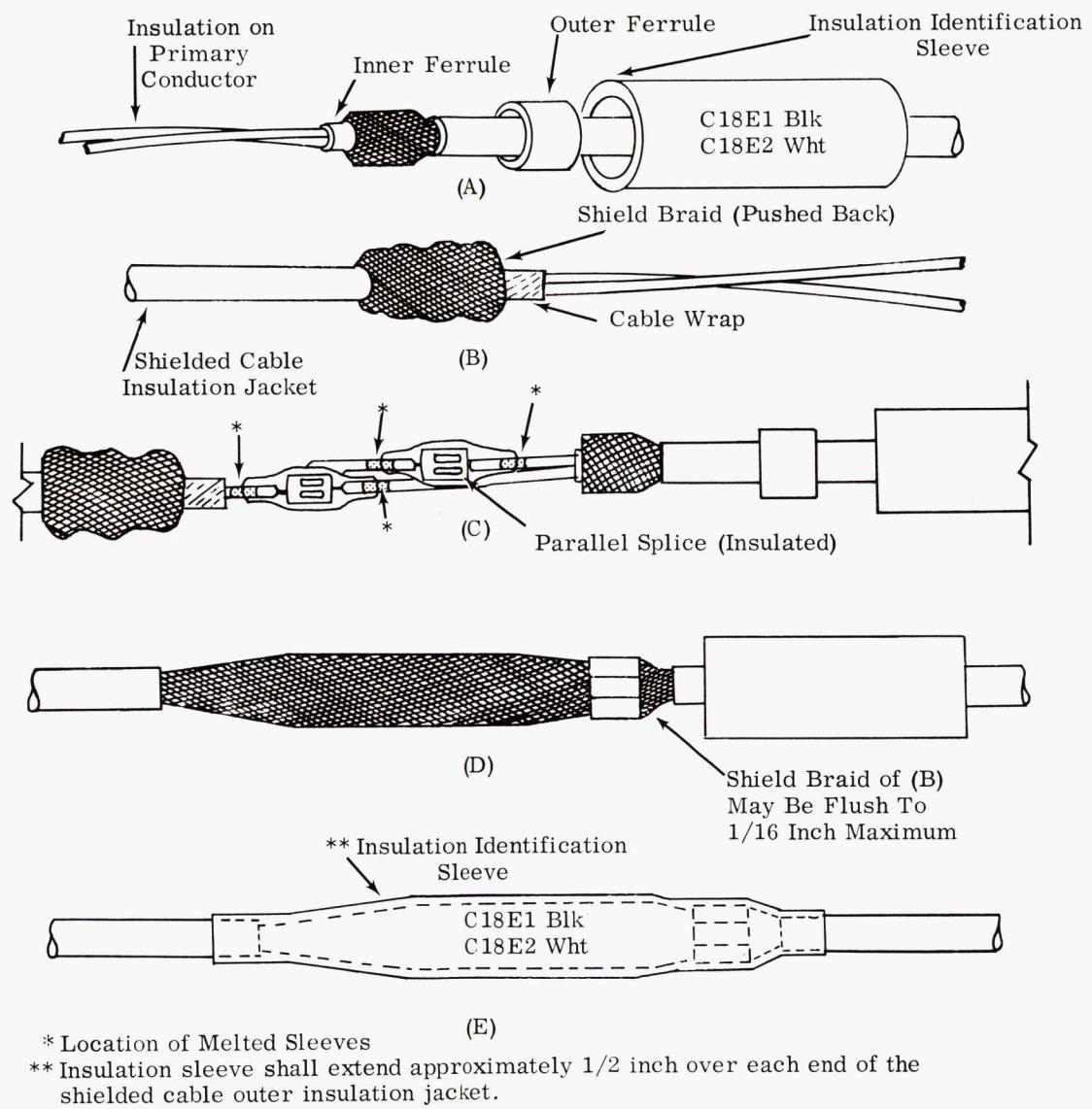
\*\* The distance between the two grounding ferrule connector assemblies shall be no more than necessary to install the parallel splice or splices properly.

\*\*\* The shield ground wire jumper shall be installed in such a way to minimize its length and shall not be taut after installation.

**NOTE:** The same method may be used for application other than single conductor shielded cables as shown, when specified on the applicable engineering drawing.

#### METHOD ONE

Figure 8-8. Splicing of Shielded Cable



#### METHOD TWO

Figure 8-9. Applying Sleeve to a Shielded Ground Wire Splice

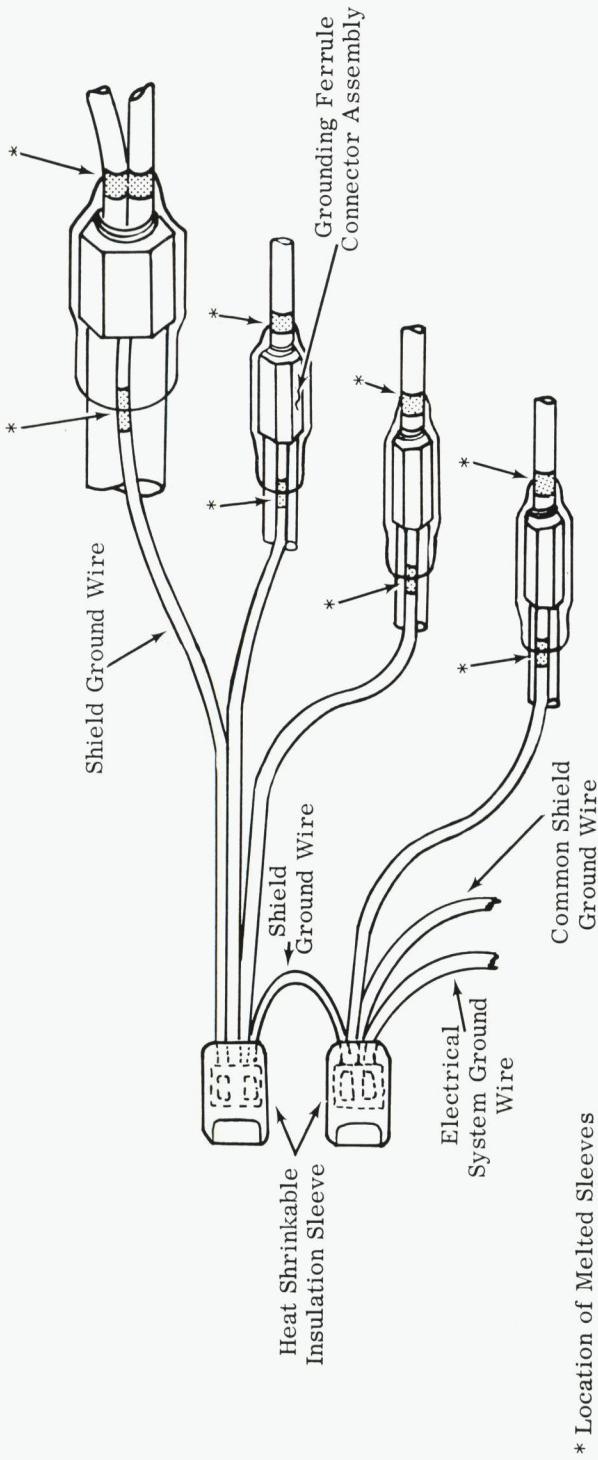


Figure 8-10. Connecting Groups of Shield Ground Wires to Electrical System and Common Ground Wire

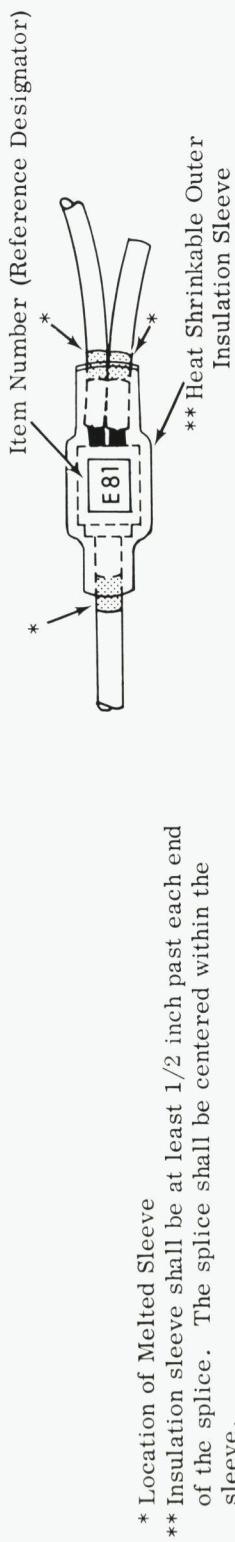


Figure 8-11. Sleeving Over Splices

## SECTION 9

### CHAFING AND CLEARANCES

#### 9.1 GENERAL

Wiring must be protected against damage that can be caused by chafing. Chafing may result from rubbing two wires against each other, one wire against a surface or edge, or against any other object. All wiring shall be handled carefully throughout all phases of installation and inspection; any cause for abrasion or breakage must be removed. Chafing is defined as wire (bundle) movement with potential frictional damage resulting from contact with edges or surfaces of parts or structure. On the following pages are some illustrations of good and bad practices regarding chafing and clearances.

#### 9.2 CHAFING

##### 9.2.1 PROTRUSIONS AND EDGES

Wire bundles shall be routed around or past protruding frames, brackets, or other objects so as not to chafe or deform the bundle or the insulation of individual wires. Figure 9-1 is an illustration of a wire bundle that has been deformed by improper routing around a structural member. Refer to Section 5 for deformation of bundles passing under clamps.

All chafe-guard material shall be free of sharp edges and burrs on the wire supporting surface.

Cables shall not contact unprotected edges, surfaces, bolts, rivets, peened rivet ends, screw ends, etc. (Refer to Figures 9-2 and 4-3).

##### 9.2.2 MOVABLE PARTS

Wires and cables that are attached where relative movement occurs (at hinges and rotating pieces) shall be installed and/or protected in such a manner as to prevent deterioration of the wires and cables by any movement of the assembly parts.

Figure 4-5 illustrates such a condition. This deterioration includes abrasion of one wire or cable upon the other and by repetitive twisting or bending.

#### 9.2.3 SLEEVES

Wire bundles shall always be protected with sleeves when contacting edges. (Refer to paragraph 4.11 and Figure 9-3.)

When tubular sleeves cannot be installed, the sleeving shall be split (shrunk if required) and tied in place by spot ties about 1/2 inch from each end. Additional spot ties will be made at necessary intervals to prevent the split from opening. The split side shall be located on the outside radius of bends (Refer to Figure 4-23.)

#### 9.3 CLEARANCES

The minimum clearance between edges and unprotected wire or cable shall be 1/2 inch except for display panels and in boxes in which cases the minimum clearance between edges and unprotected wire or cables shall be 1/4 inch. If the 1/2 inch or 1/4 inch minimum spacing mentioned above cannot be maintained by rerouting or by other approved methods, install protective sleeving to the wire or bundle and/or a chafe guard over the edge.

Any installation of cables that prevents the installation and/or removal of equipment is not permitted.

Test and maintenance points shall not be obstructed by wiring.

Proper clearance shall be observed to permit installation of cover or other protective devices without damage to electrical components and equipment. (Refer to Figure 9-4.)



Figure 9-1. An example of a wire bundle that has been deformed by improper routing around a structural member.



Figure 9-2. Cables are not properly supported and protected.

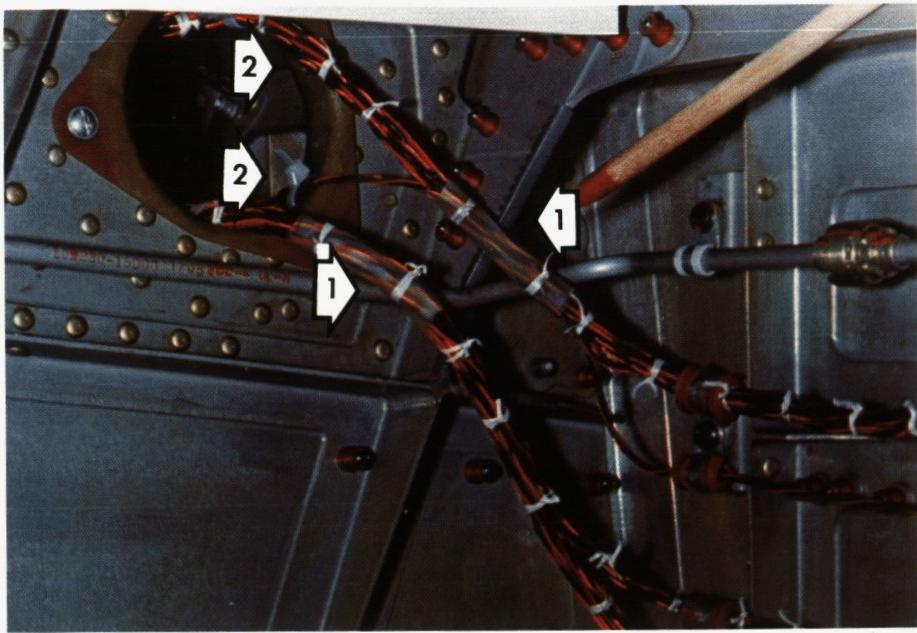


Figure 9-3. Wire bundles improperly protected by chafe guards and sleeves when passing through an opening or over fluid lines. Notice sleeves are (1) not centered over fluid lines or edges and that (2) two bundles do not have sleeves at the contact points when passing through opening.



Figure 9-4. Electrical component damage caused by lack of clearance during installation.

## SECTION 10

### POTTING, MOLDING, AND CONFORMAL COATING

#### 10.1 GENERAL

All potting, molding, and conformal coating operations shall be performed according to the applicable process specifications. Particular care must be taken during the preparation and application of potting and conformal coating to insure proper curing and adhesion.

##### 10.1.1 DEFINITIONS

Definitions pertaining to the processes mentioned within this Section are given below:

- a. Potting or Molding—Casting or injecting a liquid in, around, and throughout a part in which all parts of the form or mold remain with or are removed from the finished part after the liquid has cured.
- b. Conformal Coating—A thin uniform coating that conforms to the general configuration of the object(s) coated.
- c. Priming—The application of a liquid to a surface to aid in the adhesion of a coating of another material.
- d. Etchant—A solution that used to roughen the surface of the object to which it is applied.

##### 10.1.2 DISTINCTION

Specific distinctions can be made between potting and molding; however, for the purpose of this document, both potting and molding shall be referred to as potting.

#### 10.2 ETCHING

##### 10.2.1 GENERAL

The applicable process specifications shall be used when performing any etching operation or when handling such solutions (etchants). Etching differs from priming in that an etchant roughens the surface of the material to which it is applied.

## **10.2.2 CARE AND USE OF ETCCHANTS**

Etching solutions are extremely hazardous and shall be used only by trained personnel. Etchants that come in contact with the skin shall be removed immediately by flushing the affected skin area with LARGE quantities of water.

Etchants shall not be allowed to come in contact with water or chlorinated hydrocarbons except as stated above because an explosion may result.

### **10.2.2.1 Etchant Strength**

New etching solutions shall be made and tested before use during each shift of operations or more often if the solution becomes weak. Etching solution shall be tested by using a white Teflon wire. Wire insulation which has been properly etched will show discoloration. The absence of such discoloration indicates improper etching or a spent etching solution.

### **10.2.2.2 Containers**

In or on the spacecraft, the etchant shall be used in a container that is equipped with a cap having a slit in the end and a sponge under the cap such that the wire may be doubled and pushed through the slit and immersed in the etchant. Upon withdrawal of the wire, the sponge shall wipe off any excess etchant. The neutralizer shall be maintained and used in a similar container.

Containers of etchants shall be properly marked at all times and be tightly covered except during the actual wire dipping operation.

No other liquids or waste shall be deposited in the same containers with etchants.

### **10.2.2.3 Spills**

Spilled etchants shall be neutralized using only approved solutions. Any spilled etchant in the spacecraft shall be promptly reported and documented.

#### 10.2.2.4 Disposal

Expended etchants shall be placed in properly marked containers to be disposed of by authorized personnel only (Fire Department, Safety Office, etc.).

#### 10.2.3 WIRE PREPARATION

The wire insulation shall be cleaned with an approved solvent before etching. Contact shall be avoided between the clean insulation and any foreign matter. Wire insulation shall be etched before crimping to lugs or connectors. The conductor shall be kept out of contact with the etchant to prevent wicking by sealing or by doubling back.

##### 10.2.3.1 Application

Wire insulation shall be etched at least 1/2 inch above the area to be potted or coated.

##### 10.2.3.2 Neutralization

After etching, the wire shall be neutralized before potting or coating.

### 10.3 POTTING

#### 10.3.1 GENERAL

Electrical cables or wire bundle terminations shall be potted as required by engineering drawings in accordance with specified process procedures.

#### 10.3.2 PREPARATION

Immediately before potting, all connectors on wire bundles or cables shall be inspected for workmanship, electrical continuity, shorts, pin length, cut strands, and other testing, as required. Test probes shall not be used for these tests. Only approved devices such as break-out boxes, dummy mating connectors, etc., shall be used.

The inspector shall ensure that the assembly has been properly etched and that it is clean. Unused contact cavities shall have the contacts in place and/or be closed with the sealing plugs.

### 10.3.3 SHELL, CAN, OR MOLD SIZE

The proper size of shell, can, or mold shall be used to insure adequate coverage of the connector pins, conductors, and insulation. Unless otherwise specified, the lateral clearance from the internal parts to the surface of the potting boot or mold shall be 1/16 inch minimum. (Refer to Figure 10-1.)

### 10.3.4 GENERAL PRECAUTIONS

#### 10.3.4.1 Mating Connectors

In order to prevent misalignment or creepage, connectors to be potted shall be mated to a dummy prior to pouring the potting liquid and shall remain connected until the liquid has cured. After mating the connectors, back off the coupling nut sufficiently (about 1/4 turn) to decompress the insert materials.

#### 10.3.4.2 Clamping

Clamp or secure the object to be potted in an upright, level, and secure position to prevent any movement of the wires and to avoid any strain on the pins or terminations.

#### 10.3.4.3 Proper Centering

The wire bundle shall be centered in the mold or potting boot to prevent strain on the terminals. (Refer to Figure 10-2.)

### 10.3.5 PRIMING

All wires and the potting boot shall be primed, dried, and inspected in accordance with the applicable process specifications.

### 10.3.6 SAMPLES

Prior to potting, properly prepared potting material from each container shall be placed into a small, marked container for use as a hardness sample. The sample shall be identified with the connector or potted object, spacecraft number, and date. (Refer to paragraph 10.3.8.)

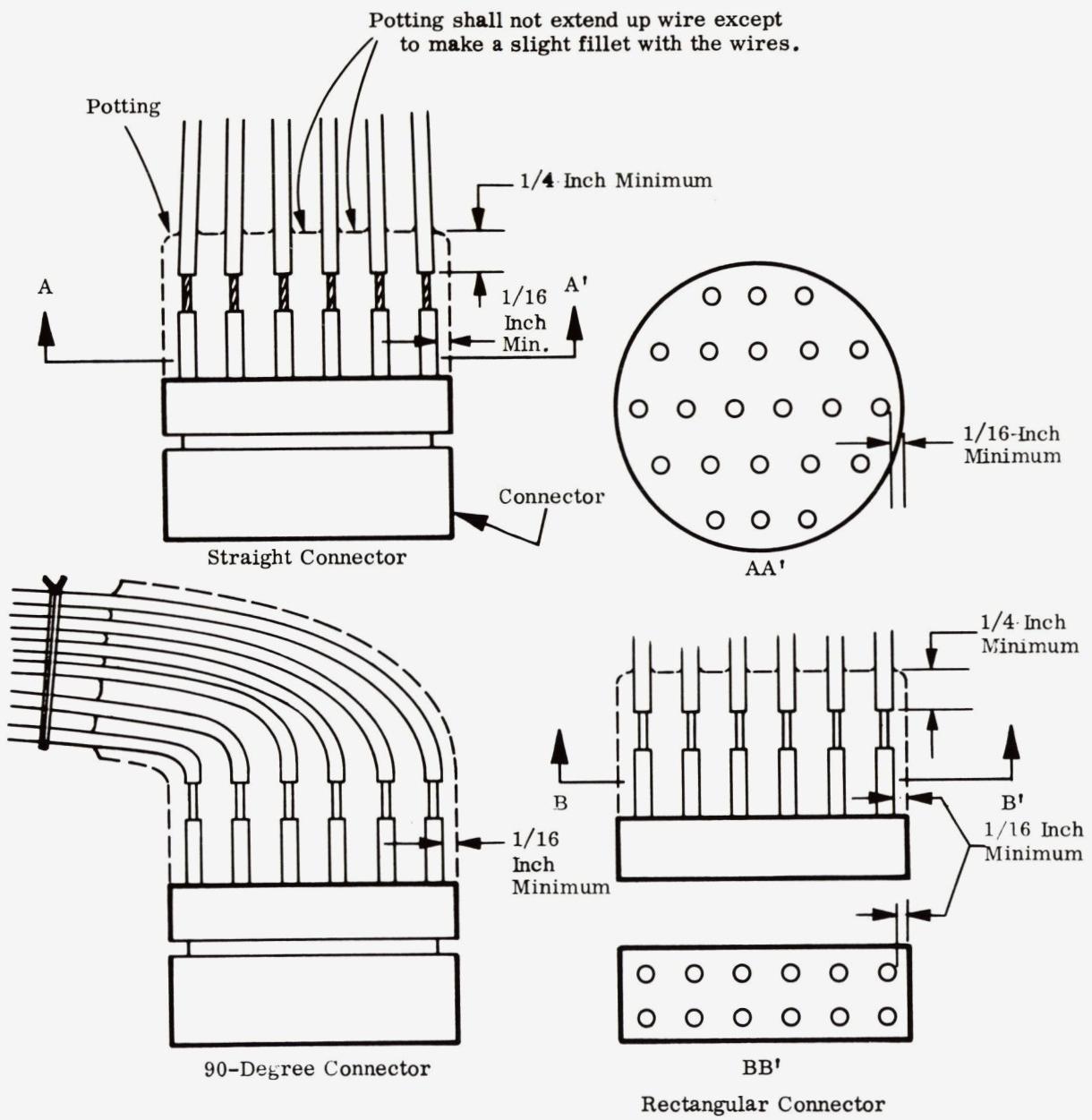


Figure 10-1. Correct Potting Methods for Connectors

#### 10.3.7 APPLICATION OF MATERIAL

The potting compound shall be carefully inserted near the bottom center of the mold. The potting compound shall flow evenly around the terminals and the inner surface of the mold until it is full. Air entrapment shall be avoided during this operation.

The potting material shall settle for five minutes and then be replenished to the required convex level. Failure to achieve a convex configuration shall be cause for rejection. Figure 10-3 shows concave surfaces which are not acceptable.

#### 10.3.8 CURING

The hardness sample (Refer to paragraph 10.3.6.) and the potted assembly shall be cured in accordance with the applicable process specifications. The sample and the potted assembly shall be inspected to ensure that proper cure and hardness have been achieved. (Refer to paragraph 10.3.9.)

#### 10.3.9 FINAL INSPECTION

The potted assembly shall be inspected to ensure that:

- a. Pin length and condition is acceptable; connector ring is free.
- b. The surfaces of the potted or molded area have no voids, blisters, tackiness, soft spots, cracks, lumps, or any defect indicative of low quality or poor workmanship. (Refer to Figures 10-2 and 10-4.)
- c. Cured assemblies exhibit good adhesion between the wires, connector shell, and coating. (Refer to Figure 10-2.)
- d. Potting shall not extend up the wire except to make a slight fillet with the wires. (Refer to Figures 10-1, 10-2, and 10-4.)

### 10.4 CONFORMAL COATING

#### 10.4.1 GENERAL APPLICATION

All exposed electrical connections that are not potted or molded shall be completely covered by a thin, approved type of conformal coating in accordance with the applicable process specifications. (Refer to Figure 10-5.)

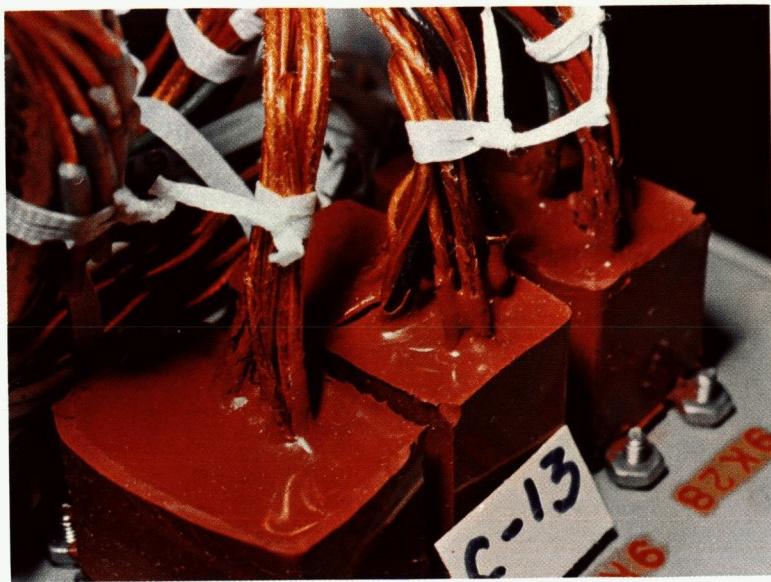


Figure 10-2. Wires not centered; the middle and right molded units have nicks; all three have foreign matter, nicks, or ragged edges; the coating extends too far up the wires, and/or poor adhesion to the wires.



Figure 10-3. Potted connectors showing concave potting surfaces which are unacceptable.

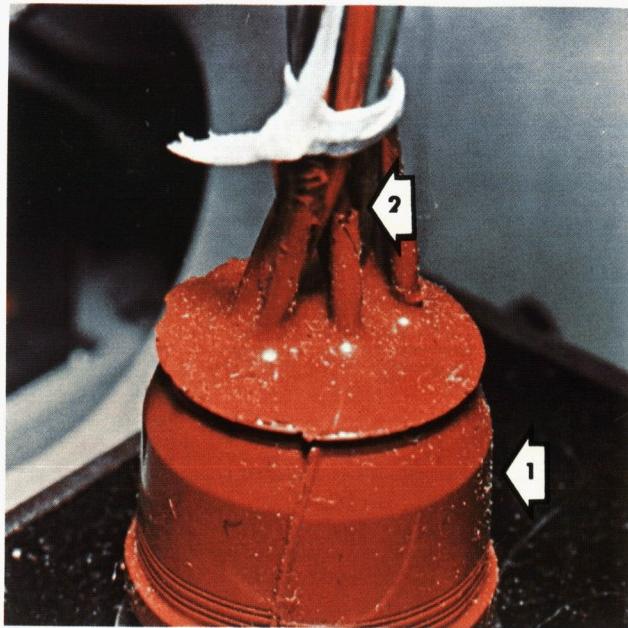


Figure 10-4. Potted connector that shows (1) foreign matter, (2) wrinkled coating under the tie—all conditions are unacceptable.



Figure 10-5. The terminal lug is exposed because of insufficient coating.

#### 10.4.2 TERMINAL STRIPS

Inspectors shall check to ensure that the following steps are used in applying conformal coating to terminal strips or other such terminations. (Refer to Figure 10-6.)

- a. After being properly assembled and inspected, terminal strips shall be cleaned with an approved solvent.
- b. If specified by the applicable procedures, a primer coating shall be applied and allowed to dry.
- c. The properly prepared coating shall be applied to the terminal(s) approximately 1/2 inch up the wire(s).
- d. When two or more wires are present, these shall be separated sufficiently to allow each wire to be completely coated. (Refer to Figure 10-6.)
- e. After curing, assemblies shall be inspected for the following:
  - (1) Good adhesion of coating to the wires and board.
  - (2) No voids, tackiness, drips, surface bubbles, blisters, dirt, or other foreign matter.
- f. Drippings, globules, or spatterings of conformal coating shall be trimmed with plastic cutting tools after the conformal coating has cured. Extreme care shall be used to avoid damage.

#### 10.4.3 PRINTED CIRCUIT BOARDS

The following criteria shall be used for inspecting the application of conformal coating to printed circuit boards:

- a. After being properly assembled and inspected, the printed circuit boards shall be cleaned with an approved solvent, and shall be handled only with approved clean, white gloves.
- b. Piston-type capacitors, other adjustable components, and board contact strips shall be masked and protected.
- c. A thin film of an approved conformal coating shall be applied and cured according to applicable specifications.
- d. After curing, the board assemblies shall be inspected for the following:
  - (1) Good adhesion between the coating and the assembled board.
  - (2) No coating on the mating surfaces of the contact strip or in any adjustable device.
  - (3) Voids, improper curing, surface bubbles, blisters, cracks, dirt, or foreign matter that would degrade the function of the coating.

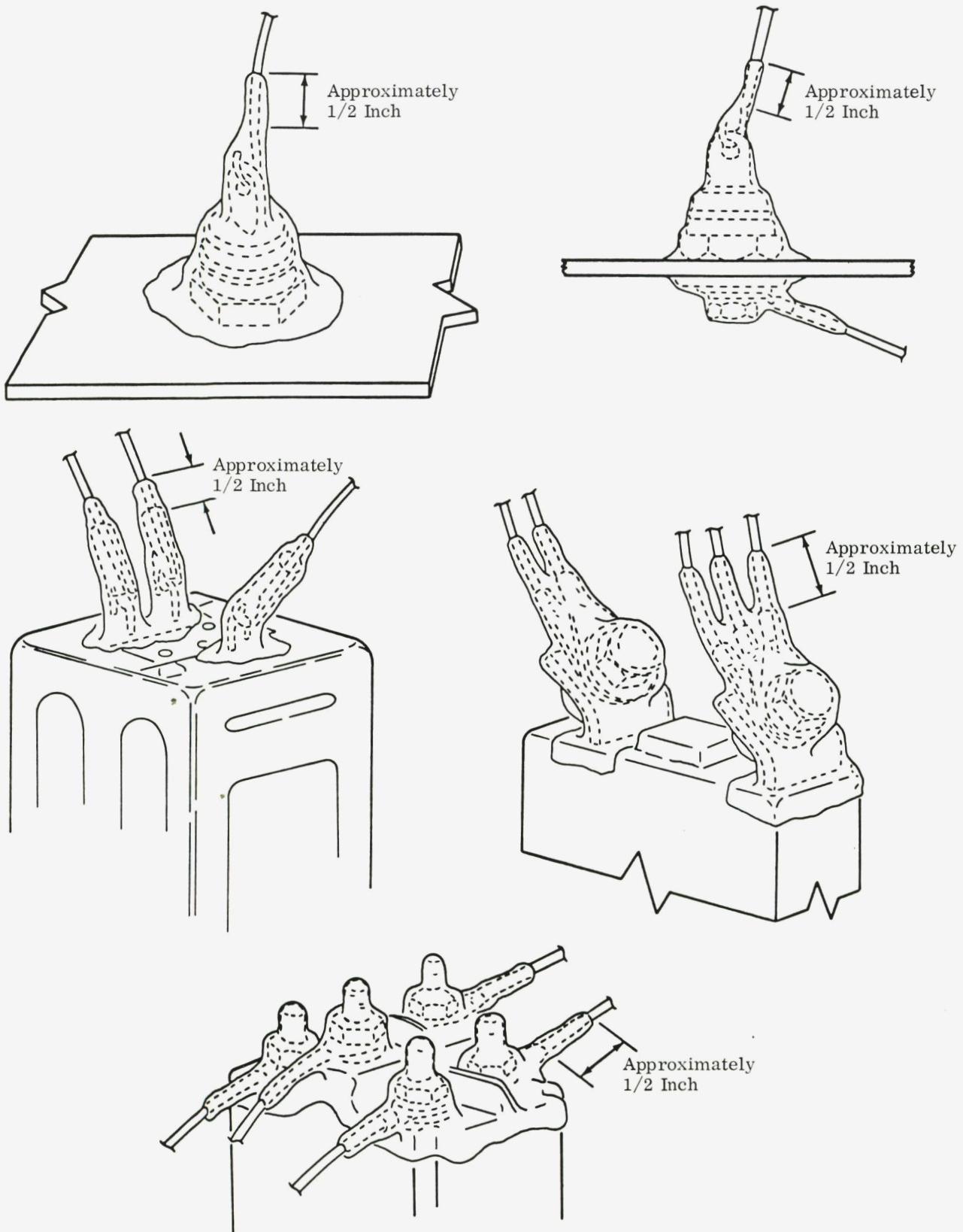


Figure 10-6. Conformal Coating on Wire Terminals

## SECTION 11

### CONNECTORS AND SAFETY WIRING

#### 11.1 GENERAL

Initially, all connectors shall be fabricated and potted according to the existing applicable process specifications and this document. When testing or troubleshooting requires probing, the wire insulation or flight connector shall not be probed with test leads. The flight connector must be demated and mated with a test connector. The pins of the test connector may then be probed with test leads. Under no circumstances shall flight connector pins or wire insulation be probed with test leads. Thereafter, the connectors shall be handled and installed using the criteria as presented in this Section. In addition, proper safety wiring practices shall be observed wherever safety wires are called for, again, by the applicable specifications.

#### 11.2 CONNECTORS

##### 11.2.1 PROTECTIVE COVERING

All connectors shall have caps or other approved protective devices installed throughout all stages of fabrication and testing. When caps are removed for pin insertion, testing, cleaning, etc., the caps shall be replaced promptly after the operation is completed. All protective devices that are used shall be of the approved flame-resistant type.

Every unused contact cavity in the connector inserts shall be sealed with a sealing plug or with an uncrimped contact and sealing plug according to the applicable process specification.

##### 11.2.2 MATING AND DEMATING

Caution shall be exercised when mating and demating connectors to ensure that damage does not occur to connector pins or sockets. Under no conditions will

connectors be subjected to undue manual force during the insertion process. In addition:

- a. All electrical connectors shall be inspected immediately after demating and prior to mating to ensure that:
  - (1) The insert faces are clean and free of chips, dirt, or anything that would damage the pins, or that would prevent them from easily entering the sockets.
  - (2) There are no bent or damaged pins or sockets or any damaged grommets. (Refer to Figures 11-1 and 11-2.)
  - (3) There are no nicks or fractures in the connector shell or inserts.
  - (4) The pin or socket ends are uniform and level.
  - (5) The plating reflects no flaking, porosity, roughness, or nonadhesion.
- b. Connectors with removable O-ring seals or grommets shall be inspected to ensure that such items are properly installed in the connector halves prior to mating them. This provision also applies to components which include connectors with removable sealing provisions.
- c. There shall be adequate wire length for bundle flexing during connector coupling and uncoupling. (Refer to paragraph 4.9.1.)
- d. Wire bundles shall not be twisted more than 1/4 turn when aligning keyways.
- e. Wire bundles shall not be pulled to obtain the required length needed to complete the mating of connectors. Any connectors that have strain relief clamps shall have these clamps assembled according to the applicable specification.
- f. The inspector shall witness the act of uncoupling of connectors and shall check the connector to see that it has not been damaged. Authorization shall be obtained from the inspector before any connectors are uncoupled, and the inspector shall record the event on approved removal records.
- g. Do not mount connector receptacles on hardware in such a manner that the rotation and locking of the coupling ring will encounter interference.

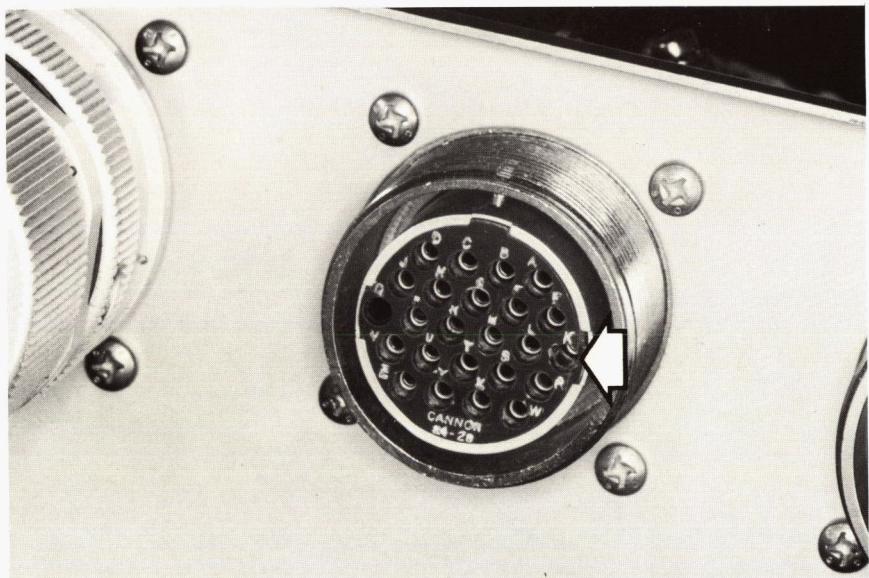


Figure 11-1. Although the pin sockets of this connector are properly identified, notice that socket "K" is damaged.



Figure 11-2. One of the pins of this connector is bent (and touches one of the other pins).

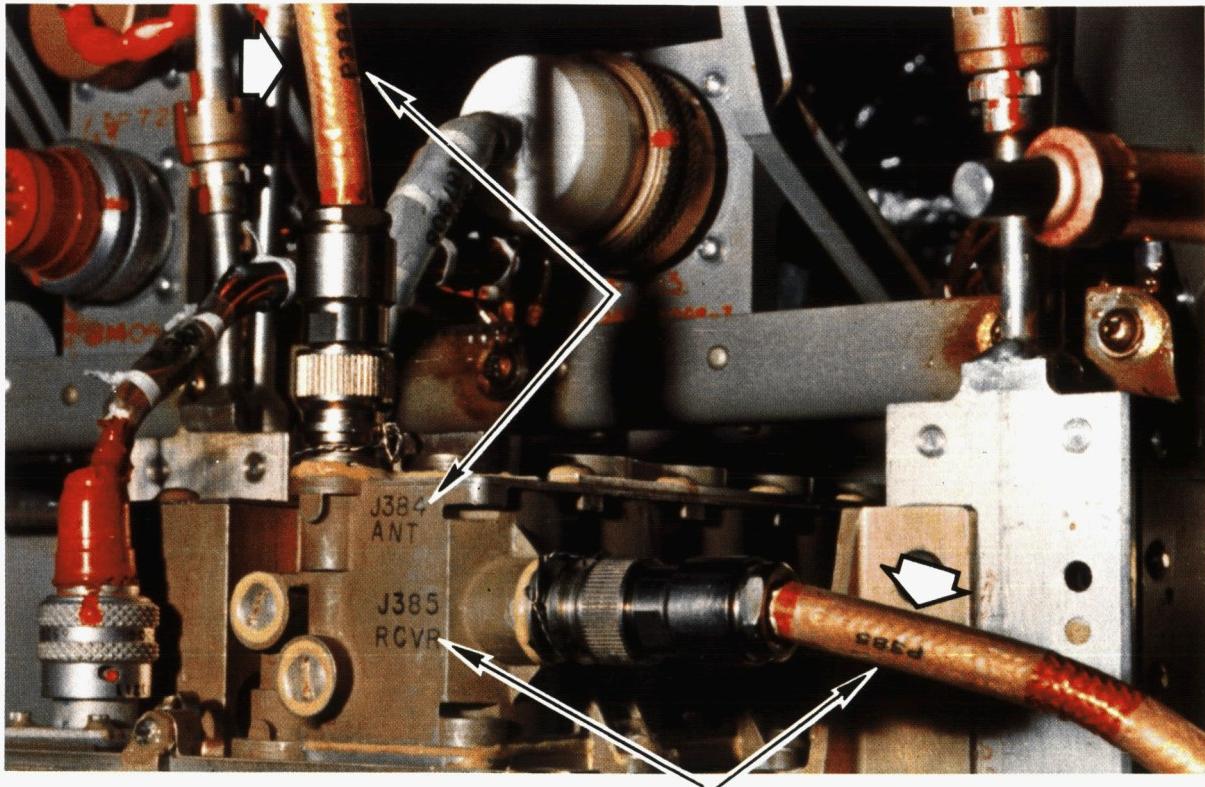


Figure 11-3. The connectors are properly marked so that P and J numbers match. Notice that the coaxial cable is identified within three inches of its termination with a clearly marked sleeve.

- h. Install feed-through-type connectors using wrenches and torque values as specified in applicable process standards.
- i. Connectors that have a threaded coupling nut shall be tightened with connector pliers that have plastic inserts. All other connector types shall be hand tightened unless otherwise specified in the applicable engineering document.
- j. If, at any time after an original test verification, a connector has been demated or damaged, a retest is required.
- k. For coaxial terminations:
  - (1) Coaxial connectors on cables shall not be twisted while mating.
  - (2) Coaxial connectors shall be hand mated until mating halves bottom.
  - (3) Coaxial connectors shall be tightened or torqued in accordance with applicable engineering drawings.
  - (4) In accordance with applicable specifications, silicone grease shall be applied to RF connector interfaces. Grease shall be applied under clean room conditions and excessive grease shall be removed.
  - (5) All coaxial cables shall be mated at both ends to their terminations before being clamped into place. Note: Simulated or dummy connections may be used to establish proper relationship of connectors to their terminations.
  - (6) Before demating a coaxial cable connection, remove enough fastenings (clamps or other fasteners) to obtain sufficient slack that will prevent strain on the cable-to-connector junction.
  - (7) Safety wiring of all coaxial connectors shall be in accordance with paragraph 11.3.

#### 11.2.3 STRAIN RELIEF OR CABLE GUIDE TYPES

All connectors that have strain relief or cable guide clamps shall have a grommet or other approved protective material installed between the wire bundle and the wire guide or strain relief clamp. This is to prevent chafing and to maintain the relative position of the wiring at the cable exit. Cushioning shall be applied on straight cable runs as well as on cable runs that exit at an angle from wire guides or strain relief clamps.

#### 11.2.4 IDENTIFICATION

Interconnecting cables, both open wire and coaxial, shall be marked as follows, according to the applicable specifications:

- a. With the appropriate wire and/or cable number.
- b. With the appropriate connector P or J designation. (Refer to Figure 11-3.) The P or J designation of the connector on the cable shall match that of the corresponding mating connector.

Both the male and female connectors shall be color coded with respect to each other.

- a. When nearby connectors are of the same or similar appearance and size.
- b. When it would be possible to attempt a mismatch by reason of wire bundle lengths and position.
- c. If the wire bundles to the connectors were incorrectly reclamped after having been unclamped.

#### 11.2.5 RADIOGRAPHIC INSPECTION

Radiographic inspection shall be used whenever necessary to verify connector integrity.

### 11.3 SAFETY WIRING

Safety wire shall be applied so that the connector will not loosen. To achieve a pulling effect, the safety wire shall not be in-line with the center of either connector, but shall be pulling in a tightening direction with respect to the two points where the wire is fastened. Refer to Figures 11-4 through 11-9 for illustrations of acceptable, typical safety wiring methods.

Whenever possible, coupling nuts shall be safety wired to coupling nuts, jam nuts to jam nuts (as when a cluster of bulkhead connectors exists). All safety wiring of the jam nuts shall be accepted prior to mating with connectors.

All cut off ends of safety wire shall be properly disposed of by using a captive type cutting tool (Refer to Figure 11-10.) and by using a visual inventory of the cut pieces.

When screw threads and connector clamps or wire guides, safety wires, etc., in the crew compartment project sufficiently to become a hazard, the projection shall be rejected. The ends of safety wires shall be anchored or tucked in.

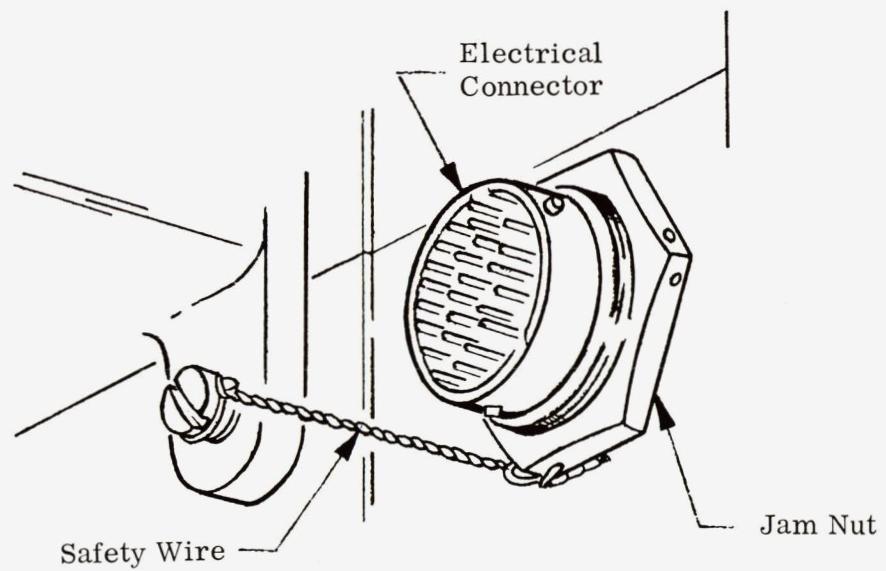


Figure 11-4. Safety Wire on a Jam Nut

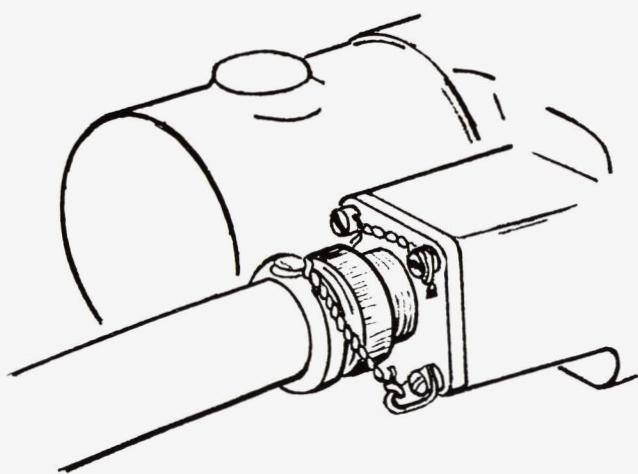


Figure 11-5. Typical Safety Wiring Installation

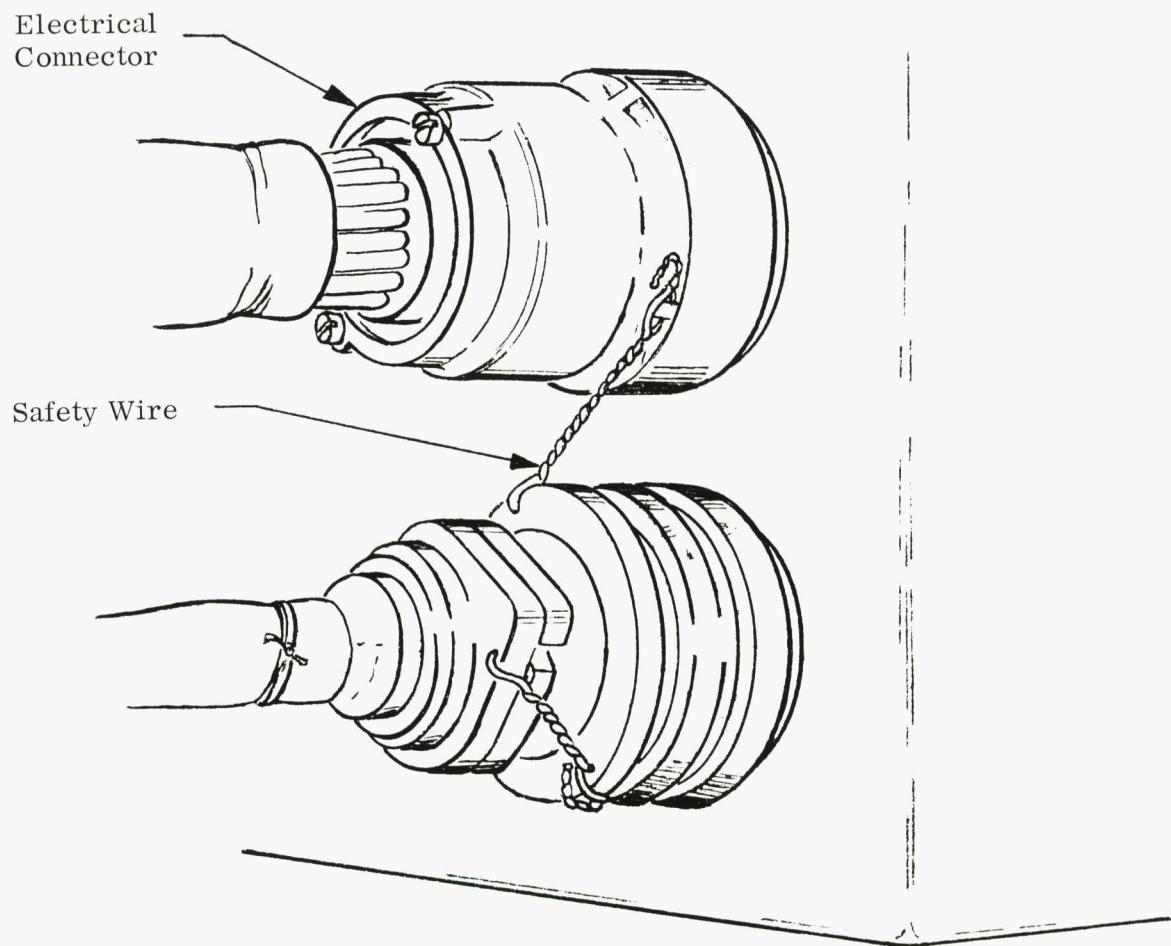


Figure 11-6. Typical Safety Wiring Installation for Two Connectors

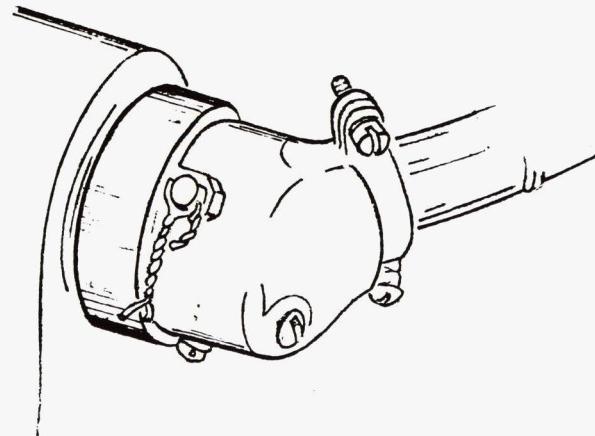
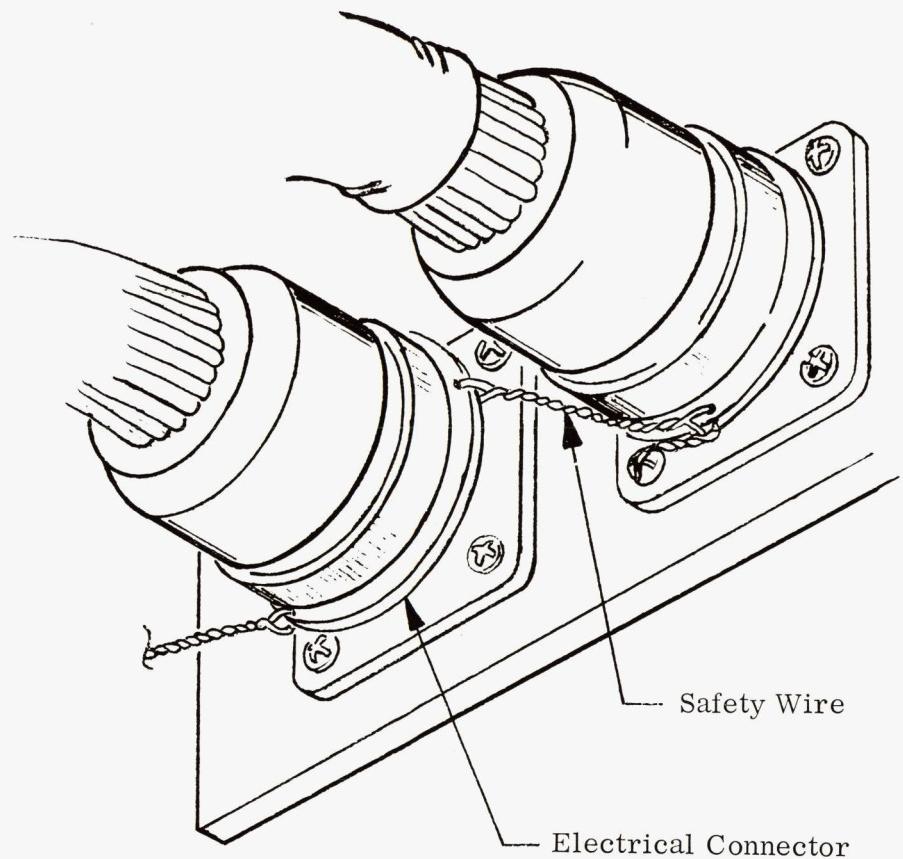
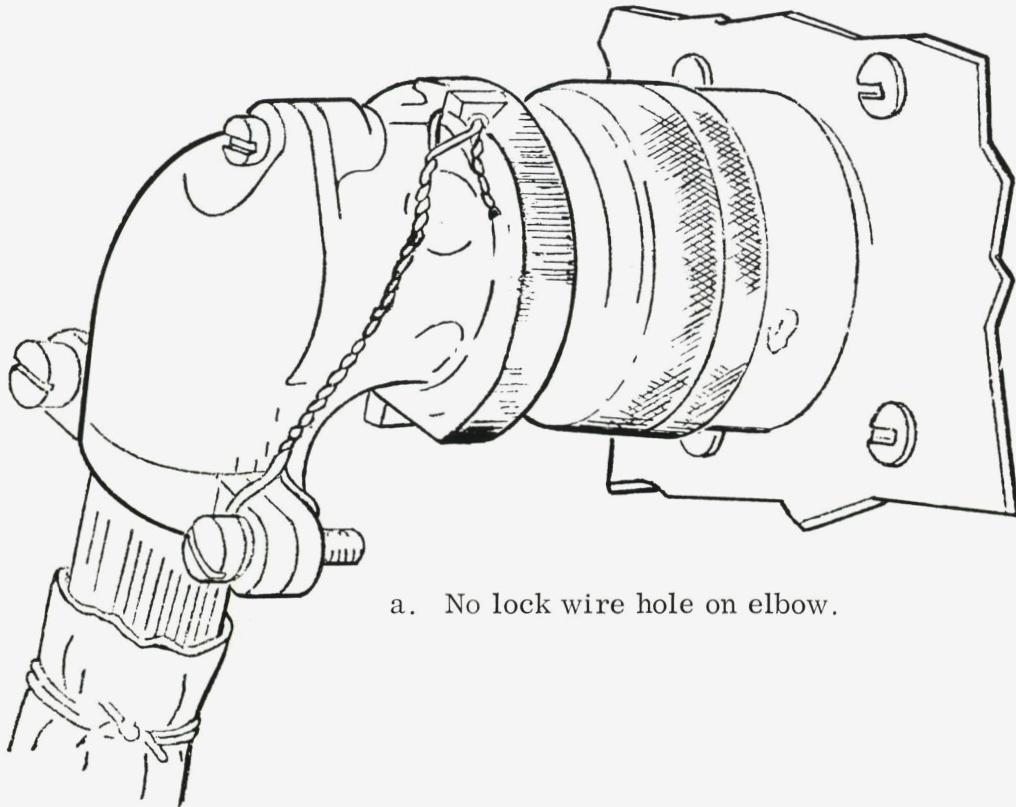
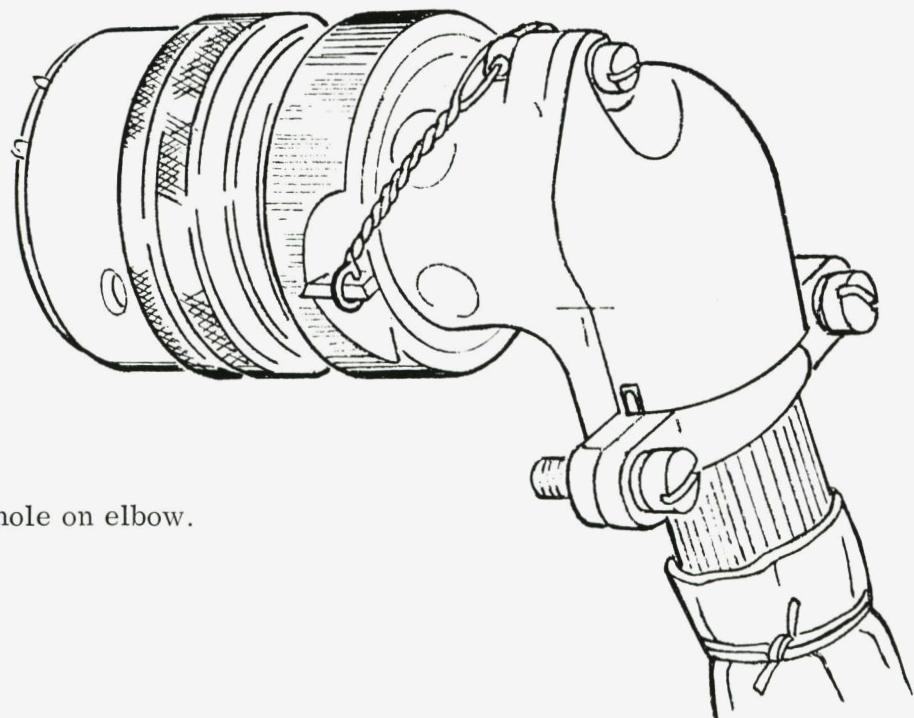


Figure 11-7. Typical Safety Wiring Installation



a. No lock wire hole on elbow.



b. Lock wire hole on elbow.

Figure 11-8. Typical Safety Wiring Installation for Elbow Connectors

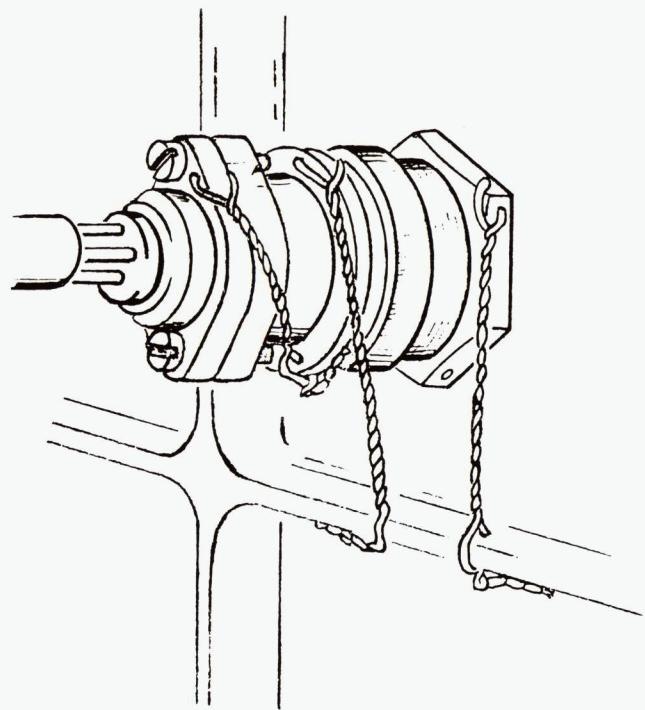


Figure 11-9. Typical Safety Wire Installation to Structure

A typical wire-cutting device  
that holds the cut part during  
and after cutting.

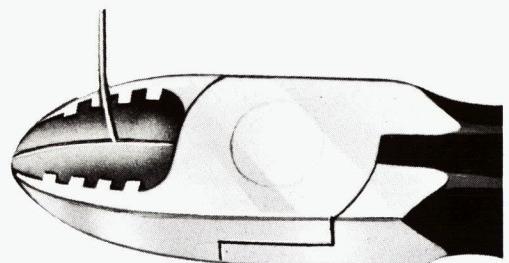


Figure 11-10. Typical Captive Wire-Cutting Device

## SECTION 12

### STOWAGE

#### 12.1 GENERAL

This section sets forth stowage inspection criteria for flight and nonflight equipment used for spacecraft fabrication, rework, testing, and transportation.

For the purpose of this document, stowage is defined as: The state or manner of securing material for situations not normally detailed on assembly drawings or in test procedures.

Proper stowage will provide protection of the quality already built into the existing hardware.

#### 12.2 ACCESSORY EQUIPMENT AND FACILITY STOWAGE

Preplanning of work requirements will minimize problems involving fabrication accessories. Bulky electrical drop cords, pneumatic hoses, vacuum lines, tool kits, lamps, and similar service equipment, due to their size and weight, can do damage to spacecraft and cause contamination traps, work hazards, and personnel inconveniences. To preclude these problems, Quality Control will inspect all work stations to assure that preplanning did provide for the following:

- a. Sufficient convenience outlets close to the area requiring this service. These are to include semipermanent electric, air, and vacuum lines at, on, or within the spacecraft.
- b. Spacecraft lighting essential for fabrication and inspection utilizes semi-permanent installations at, on, or in spacecraft. (Refer to Figures 12-1 and 12-2.)
- c. Protective shields are provided for lighting sources to confine broken glass in case of accidental damage. Mercury lights shall not be used. (Refer to Figure 12-1.)

- d. Customized fixtures are provided on rigs and in spacecraft cabin areas to:
  - (1) Support tools.
  - (2) Provide hand holds and foot pads.
  - (3) Support heavy or bulky accessories.
- e. Handling aids are attached to delicate or bulky flight equipment for protection, ease of lifting, support, holding, or handling prior to its permanent installation and/or rework. These handling aids shall be distinctively colored and marked and must be removable prior to flight. (Refer to Figures 12-3 and 12-4.)
- f. Areas of the spacecraft that will, through necessity, have personnel and/or equipment traffic are protected to prevent damage to the spacecraft or to the equipment.
- g. Protective covers for the spacecraft areas that are vulnerable to physical damage or to the collection of debris. The covers in themselves must not become entrapped by the follow-on assembly operations.
- h. Protective nonflight covers/shields shall be colored to contrast with the surrounding spacecraft to insure removal prior to flight. (Refer to Figure 12-5.) Bright colors should also be used on flags that are attached to such items. (Refer to Figure 12-6.)
- i. Waste containers are conveniently placed in and around spacecraft for quick and positive disposal of debris.
- j. Manufacturing accessories which generate heat, such as lamps, soldering irons, brazing tools, or heat guns have adequate fixtures to shield residual heat from causing spacecraft damage. (Refer to Figure 12-7.)
- k. Maintenance review is made of accessories to prevent use of shopworn equipments.
- l. Nonmetallic protective shields used for stowage are manufactured of approved materials.

### 12.3 DURING ASSEMBLY/DISASSEMBLY

Installation of equipment may not be completed for many legitimate reasons such as shift changes, weekends, delays in retrofit, long-time repair periods, parts delivery, etc. Stowage requirements on drawings could not possibly cover the number of conditions that may arise during the assembly or disassembly operations. During fabrication, partially installed equipment may require stowage that

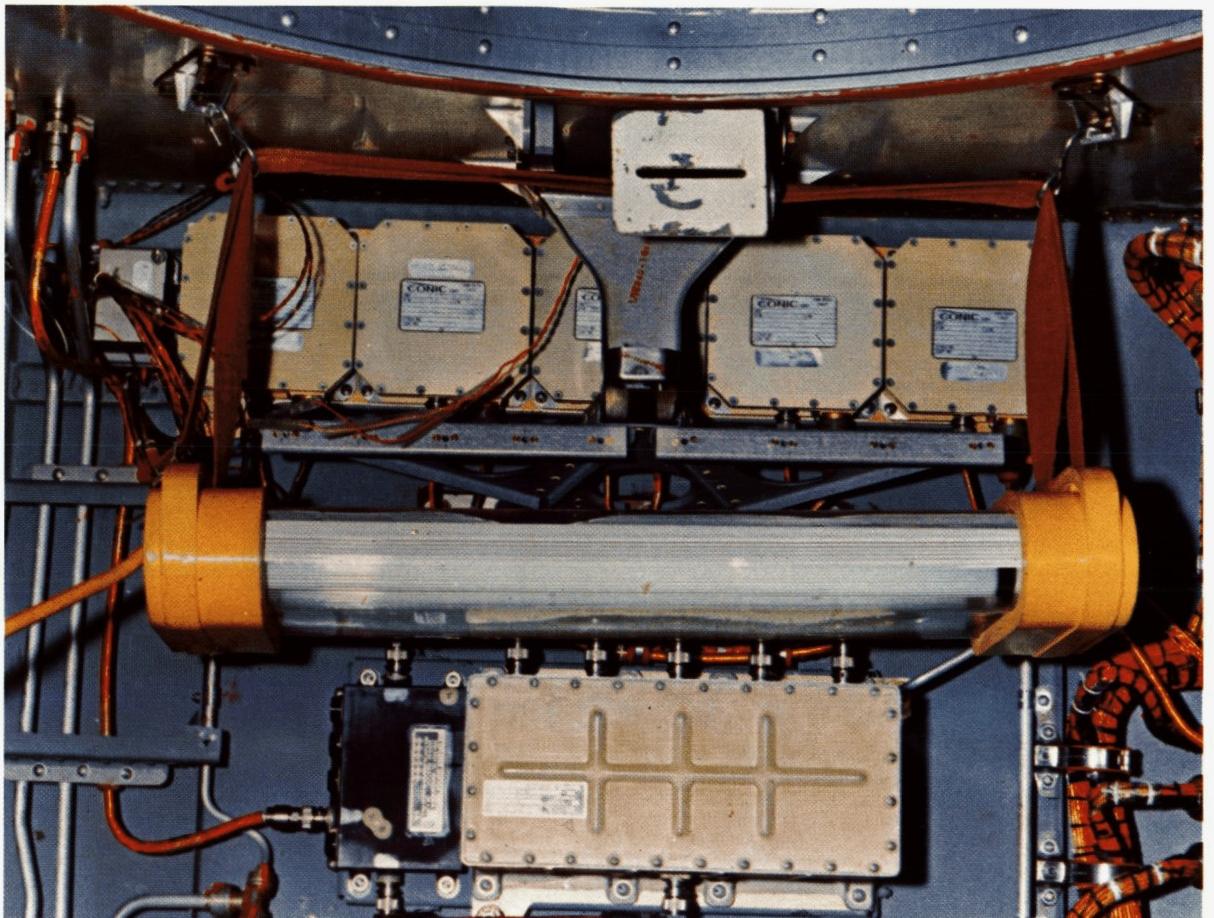
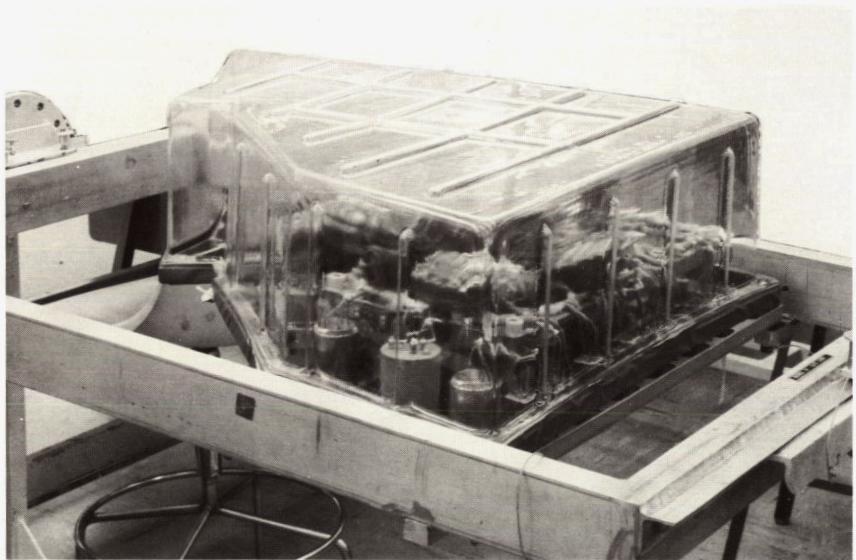


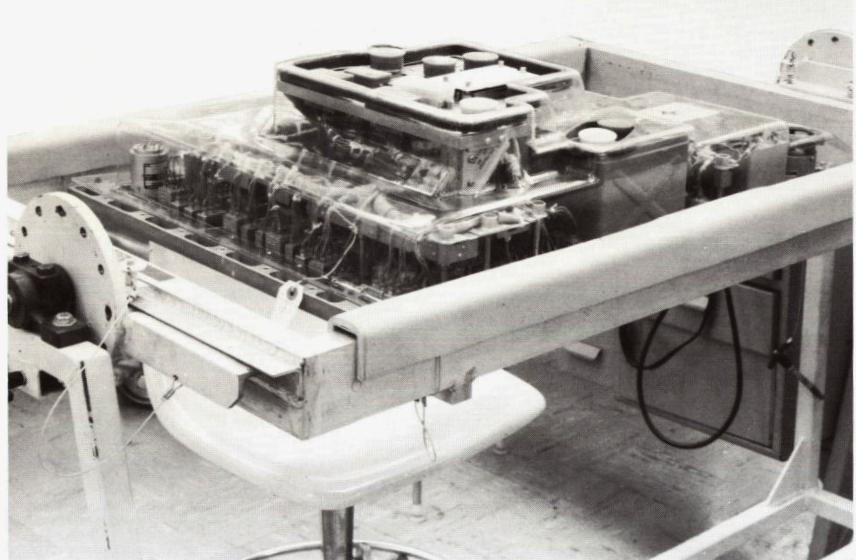
Figure 12-1. A semipermanent lighting fixture in the spacecraft has a protective shield to confine broken glass in the event of accidental damage. Also notice the rubber pads at the ends of the fixture.



Figure 12-2. This semipermanent light fixture is adequately protected against glass breakage, but notice that the fixture is dangling and supported by only one hook. (Figure 12-1 shows a better way to hang the light.)



- a. A molded plastic cover is used during fabrication to keep dust from the display panel.



- b. In addition to the molded plastic protection, notice that the display panel is mounted on a rotatable fixture for ease of handling while working on either side of the components.

Figure 12-3. Handling Aid With Molded Plastic Protective Cover

was not detailed on drawings. Similarly, the assembly and disassembly of individual components for replacement, repair, or retrofit also involve temporary stowage. Retrofit programs may obsolete portions of systems which cannot be completely removed from the spacecraft. Permanent stowage of the obsolete equipment must be provided. To cover such situations as described above, inspection personnel will assure that the following stowage requirements are implemented:

- a. Electrical equipment awaiting installation are properly stored.
- b. Incomplete harness installations are supported at all times to prevent damage. (A stowed cable is to be secured within 1/2 inch of its connector to prevent damage.) (Refer to Figure 12-9.)
- c. Auxiliary support devices are provided for equipment to prevent it from being dependent for support upon wires, cables, or harnesses during repair, retrofit, or partial installation. (Refer to Figure 12-8.)
- d. Stowed wires and cables are readily identifiable at all times.
- e. Stowed equipment is not used as a support, step, or handhold.
- f. Stowage of wires and harnesses precludes damage from high temperature equipment.
- g. Uninstalled connectors are capped with a compatible locking cover or bagged to prevent damage. (Refer to Figure 12-8.)
- h. Stowed wires and cables are not damaged due to interference with moveable controls, hinged panels, shock-mounted assemblies, etc.
- i. Dead-ended wires have specific identification and are properly stowed. (Refer to Figure 14-4.)
- j. Positioning of stowed equipment prevents contamination, condensation damage, etc.
- k. Drip loops are provided, when temporarily stowing cables and harnesses, to prevent fluids and condensation from entering receptacles.
- l. Limited personnel access to an area when bulky equipment or a long harness run is temporarily stowed.
- m. Caps, plugs, and receptacles used as protective covers for quick disconnects, test points, etc., are secured at all times to prevent contamination or damage to the equipment. (Refer to Figure 12-8.)

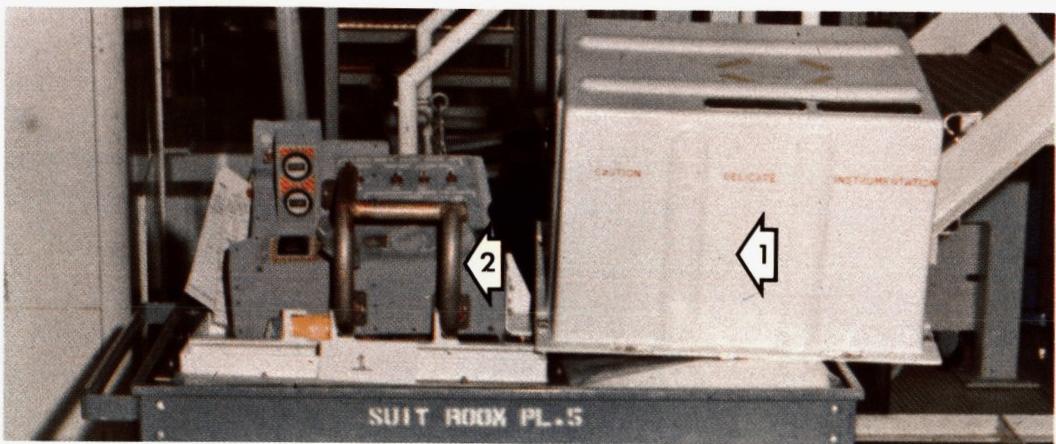


Figure 12-4. The dust cover (1) has been removed to show the handling fixture (2) that is affixed to aid in lifting the panel assembly; however, the handling aid should be distinctively colored and marked "Remove Before Flight."

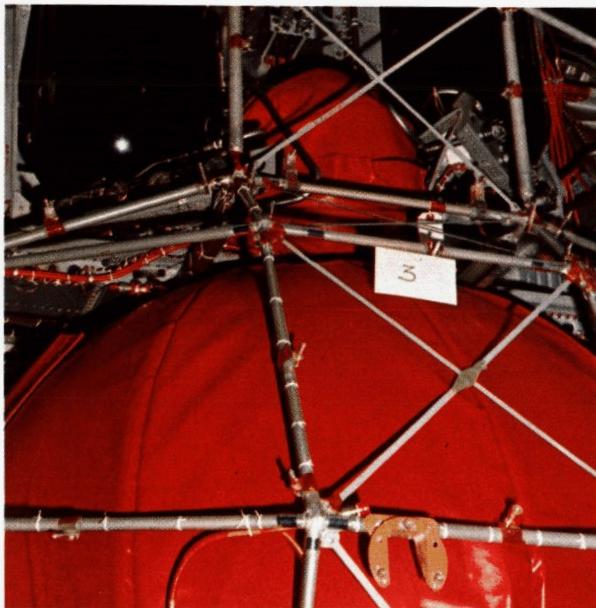


Figure 12-5. The tank cover affords protection against scratches, falling debris, etc., during all phases of assembly. The bright red color of the cover in contrast to other objects is to assure its removal prior to flight, but should be marked "Remove Before Flight."

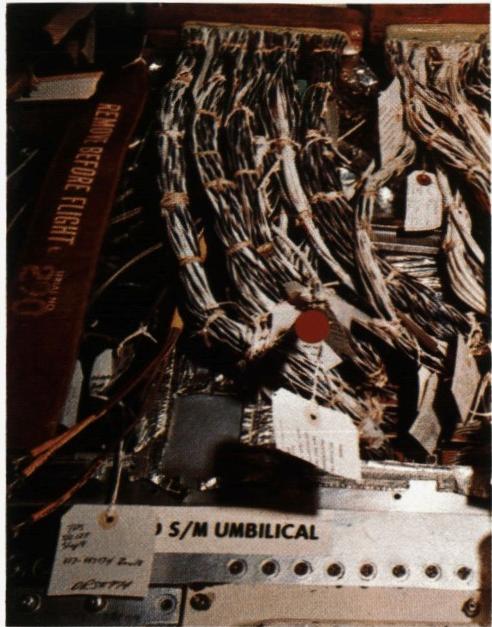


Figure 12-6. Be certain that "Remove Before Flight" flags are of bright contrasting color to ensure the item is conspicuous.

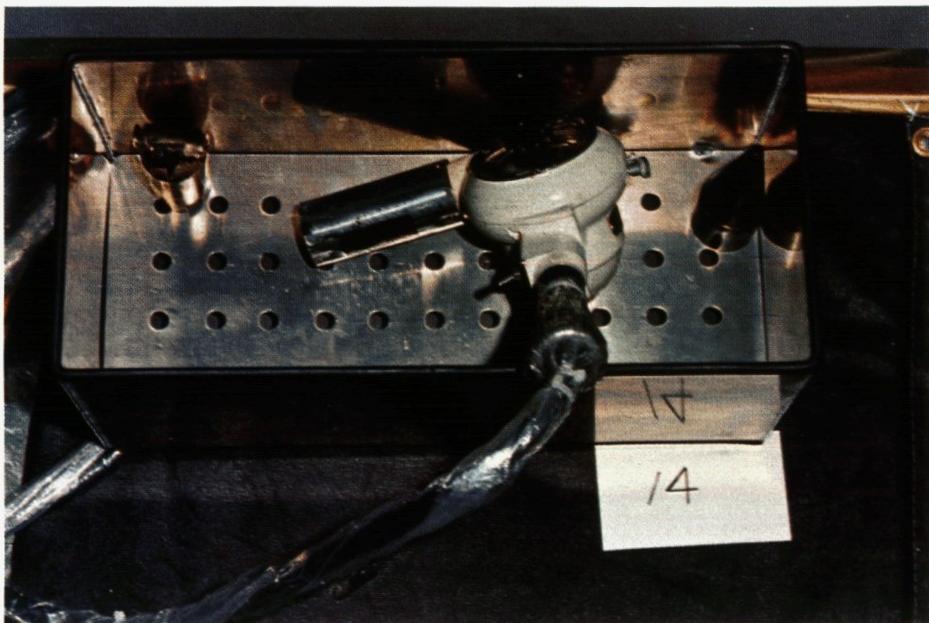


Figure 12-7. The special box for the heat gun and accessories helps to prevent residual heat from causing damage to the spacecraft.

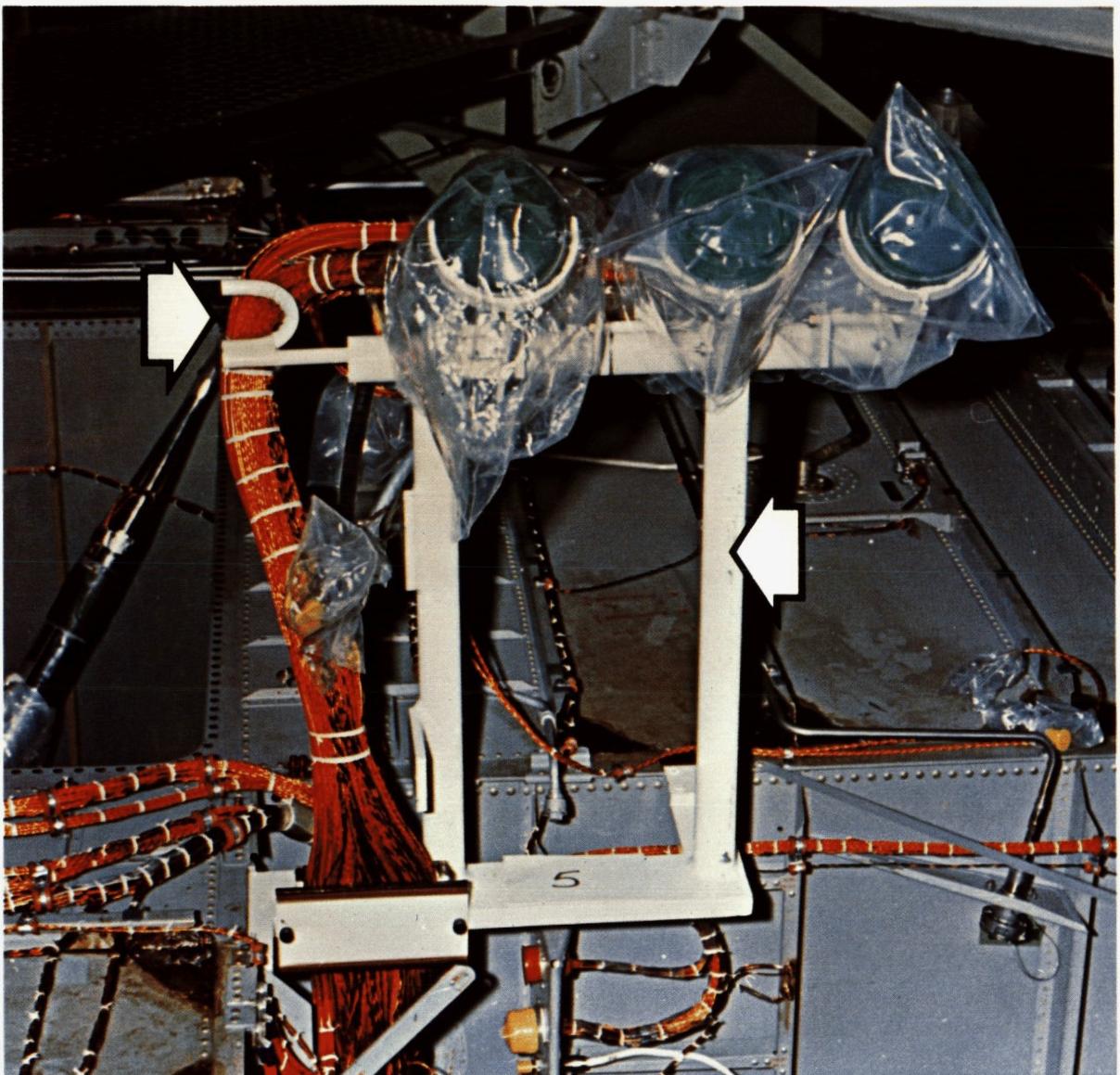


Figure 12-8. An auxiliary support device is provided to support the wire cables and harnesses during repair or partial installation. Note the arm at upper left of fixture to prevent flexing of the harness.

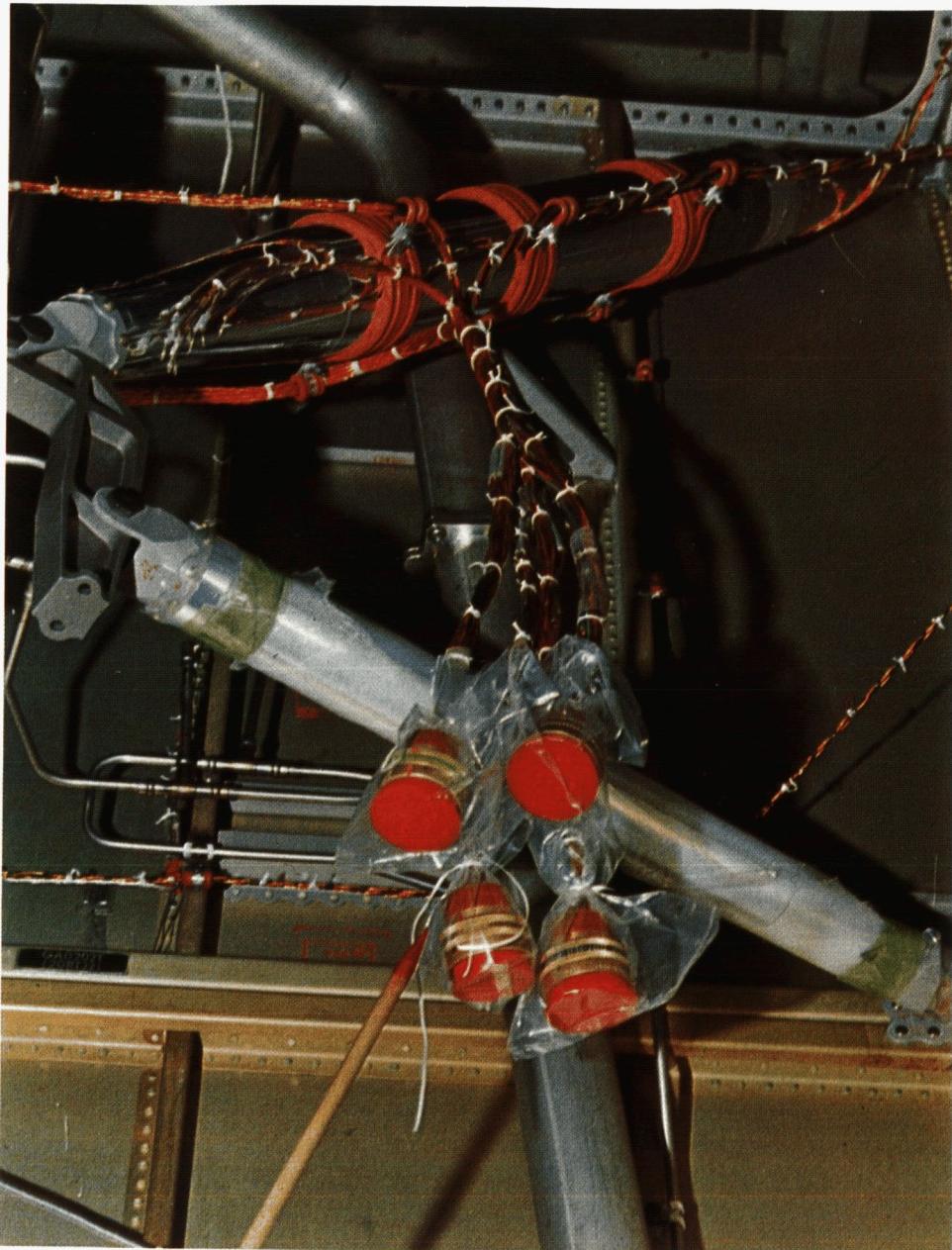


Figure 12-9. The wire harness is improperly stowed because no drip loops have been included to prevent fluids from entering the connectors. Also, the harness is not secured such that it dangles and supports its own weight.

- n. Adequate stowage of temporary caps, covers, and guards during test is provided and controlled. (Log book control shall be used.)
- o. Cables or harnesses are adequately secured in such a manner that they do not support their own weight. (Refer to Figure 12-8 and 12-9.)

#### **12.4 DURING TRANSPORTATION WITHIN A FACILITY**

Preparations for internal transportation frequently do not consider stowage requirements. Stowage for transportation, therefore, becomes a major concern of the inspector. Protection must be provided to maintain the quality of the product. The same stowage considerations that exist for interplant transportation must also be considered for partially completed installations while being transported from one building to another or from one work area to another. Loose dangling wire, cables, harnesses, partially secured packages, panels, etc., tend to damage hardware.

All of the stowage considerations therefore, delineated in the paragraph 12.3, are also considerations for the inspection of intraplant transportation stowage.

Inspection personnel will assure that:

- a. Adequate packaging for weight, shape, and type of component or units is used to afford full protection from damage at all times.
- b. Adequate protection is taken when hardware may be exposed to the elements, during transportation and, whether indoors or out, against such things as flying chips, rain, dust, heat, etc.
- c. Personnel are implementing the necessary precautions during the handling of this material.
- d. Packaging protection used when moving equipment is adequate to support the weight, size, shape, and critical nature of the material and to protect from shocks, vibrations, and jolts such as crossing of railroad tracks, cobblestone roads, etc.
- e. The same protection is available at destinations as was afforded at the source, such as storage facilities, personnel handling, and transportation media from vehicle to storage areas.
- f. Duration of travel be planned so that shipment will not be stranded at destinations because of unavailability of receiving personnel or equipment.

## 12.5 DURING TESTING

Inspection personnel will assure that:

- a. Adequate stowage of temporary caps, covers, and guards during test is provided and controlled. (Log book control shall be used.) All such caps, covers, and guards shall have serialized streamers attached. (Refer to Figure 12-6.)
- b. Test equipment which is used in and out of spacecraft is adequately supported. Test cables or equipment shall not support their own weight when attached to flight equipment. (Refer to Figure 5-3.)
- c. Test equipment is validated as being compatible with environmental conditions in spacecraft prior to testing.
- d. Heat generated from test equipment is properly vented. Concentrated heat will be diffused by means of an air stream or an air exhaust device.
- e. Test equipment brought into the spacecraft is kept to a minimum.
- f. Personnel requirements are not exceeded in the spacecraft.
- g. Only those items of test equipment which are specifically called out on approved test procedures shall be used inside the spacecraft.

## SECTION 13

### TOOL AND EQUIPMENT CONTROL

#### 13.1 GENERAL

This Section defines the inspection criteria associated with controlling the calibration and verification of tools, machines, and test equipment that are used in the fabrication, installation, modification, repair, and test of electrical and electronic components. These criteria and standards are supplemental to the following documents referenced in paragraph 1.3.2:

- a. NHB 5300.2, Apollo Metrology Requirements Manual.
- b. MSC-SPEC-C-5A, Specification for Apollo Spacecraft Cleanliness.
- c. MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections.
- d. NPC 200-4, Quality Requirements for Hand Soldering of Electrical Connections.

Calibration, as used in this document, refers to the comparison between two instruments or devices one of which is a standard of known accuracy that is used to detect, correlate, report, and/or adjust any variation in the accuracy of the instrument or item being compared.

Verification, as used in this document, refers to a category or status that is given to equipment or a system which requires frequent or daily comparison with higher accuracy inspection, measuring, or test equipment. Detailed adjustments or recording of variables are most logically performed by personnel who operate and maintain this equipment. An equipment log is required for each piece of equipment so categorized.

#### 13.2 ACCEPTABLE PRACTICES IN GENERAL

##### 13.2.1 CALIBRATION

All equipment that requires calibration shall be initially calibrated and recalibrated at scheduled intervals against certified standards which have known, valid relationships to those of the National Bureau of Standards. Records shall be maintained

indicating the date of last calibration and the next due date. Identification attesting the due date of the next calibration shall be displayed on each item of inspection, measuring, and test equipment or tools. Periodic operational checks shall be performed prior to the use of each item of inspection, measuring, and test equipment.

Mechanical and electrical test equipment shall be calibrated at scheduled intervals in accordance with an approved calibration procedure. Nonre-usable seals shall be placed on all external adjustment places. Any visible damage or erratic operation of the item is justification for its removal from service.

#### 13.2.2 CLEANLINESS

All tools and equipment that are used in areas with controlled environment shall be cleaned in accordance with MSC-SPEC-C-5A, Specification for Apollo Spacecraft Cleanliness.

#### 13.2.3 SERVICING

Tools and equipment shall be returned to the tool control facility at scheduled intervals for cleaning, servicing, inspection, and replacement. Tools and equipment that are found detrimental to good workmanship or safety shall not be used.

#### 13.2.4 TOOL SELECTION

Tool selection shall be such that the measurement to be made or the operation to be performed lies within the calibrated range of that tool.

### 13.3 CRIMPING TOOLS AND IMPACT-TYPE INSERTION TOOLS

#### 13.3.1 CERTIFICATION

Crimping tools and impact type insertion tools, both manual and power driven, shall be certified for specific wire size, connection size, and type prior to use as specified in MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections.

Upon completion of initial certification, a recall cycle shall be established for all crimping tools in accordance with MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections.

#### 13.3.2 INTEGRITY SEALS

Calibrated and certified tools shall be sealed to insure against unauthorized alteration of adjustment settings. A wire and lead-seal method shall be used if the tool has provisions for it; otherwise, the tool shall be sealed by a nonre-usable decal seal which will be visibly damaged if the calibrated or certified setting is altered. Seals shall be placed on all external calibration adjustment points on the tools. Any broken seal shall be cause for rejection. (Refer to paragraphs 13.2.)

#### 13.3.3 MARKINGS

Each tool shall be marked to identify completely the wire size and type of termination for which it was calibrated.

#### 13.3.4 TOOL VERIFICATION

Crimping tool certification shall be verified for wire size and proper crimp dimensions. Impact-type insertion tools shall be verified for proper insertion force prior to each issuance of the tool.

Tool verification shall be witnessed by an inspector. Verification of crimping tools shall be accomplished by testing with go/no-go gages. A minimum of three test samples shall be prepared for each lot by the operator and shall be submitted for inspection and evaluation prior to crimping. In the event the samples fail, the tool shall not be used. Tensile testing shall be in accordance with MSC-SPEC-Q-1, Specification for Crimping of Electrical Connections. At the end of the lot or end of the shift, the operator shall prepare three samples and submit them for inspection and evaluation prior to returning the tool to the tool control facility. If the samples fail, the production crimps made by that tool shall be rejected, and the tool shall be marked as defective.

Tensile strengths must meet the minimum requirements of Table 13-1. Tools must be returned to a tool control facility at the completion of each lot or at the end of

each shift (maximum 12-hour shift), and calibration shall be verified. A lot is defined as any amount of connectors, pins, or plugs of one size produced on a continuous basis by one operator on one shift from one batch of material.

Wire sizes other than those listed may be used only with the written approval of MSC.

Table 13-1  
Crimped Tensile Strength

Wire Gauge	Terminal Lugs Load in Pounds (Minimum)	Connector Contacts Load in Pounds (Minimum)
30	60% of wire tensile strength	60% of wire tensile strength
28	60% of wire tensile strength	60% of wire tensile strength
26	60% of wire tensile strength	6
24	10	8
22	15	12
20	19	20
18	38	40
16	50	50
14	70	70
12	110	110
10	150	150
8	225	225
6	300	300
4	400	400
2	550	550
1	650	650
0	700	700
00	750	750
000	825	825
0000	875	875

### 13.3.5 SPECIAL REQUIREMENTS

Insertion and removal tools shall be visually examined for defects. Tools that have burrs, cut edges, bent shafts or edges, or other defects shall be tagged and returned to the tool control facility. Any crimping tool, insertion tool, or extraction tool which is detrimental in any way to the finished product shall also be removed from operation; the problem shall be noted and attached to the tool by the inspector; and the tool shall be returned to the tool control facility.

## **13.4 HEAT GUNS**

### **13.4.1 TEMPERATURE CONTROL**

Heat guns shall use a means to stabilize temperature control. Since output temperature is variable and proper temperature is critical, the temperature for shrinking all heat-reactive sleeves shall be as recommended by the manufacturer.

### **13.4.2 REFLECTORS**

Reflectors shall be used at all times and shall have a configuration that cannot be altered. The heat range of a reflector shall be verified with the specific heat gun with which it will be used, as often as is necessary, to maintain the quality of the product.

Heat reflecting shields shall be used to protect adjacent areas.

### **13.4.3 CONTROLLED CYCLE HEAT GUNS**

Controlled cycle heat guns shall be calibrated and used only on approved materials as stated by specifications from the manufacturer.

## **13.5 INSULATION STRIPPERS**

### **13.5.1 THERMAL TYPES**

Thermal-type insulation strippers shall be used where practicable. (Refer to Figure 13-1.) When required for personnel safety, an exhaust hood and fan ventilation system shall be used to exhaust toxic fumes while stripping insulation.

The temperature of the heating elements shall be such as to readily melt the insulation without burning or charring the insulation or without damaging the conductors.

Elements shall be clean and free of all foreign matter such as oxides, lint, insulation scraps, etc.

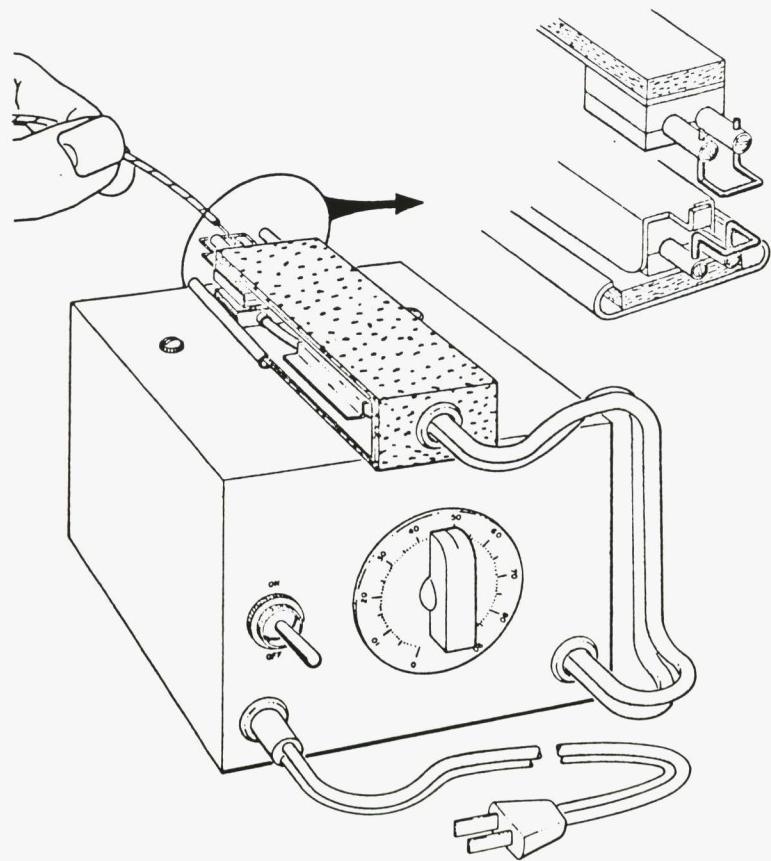
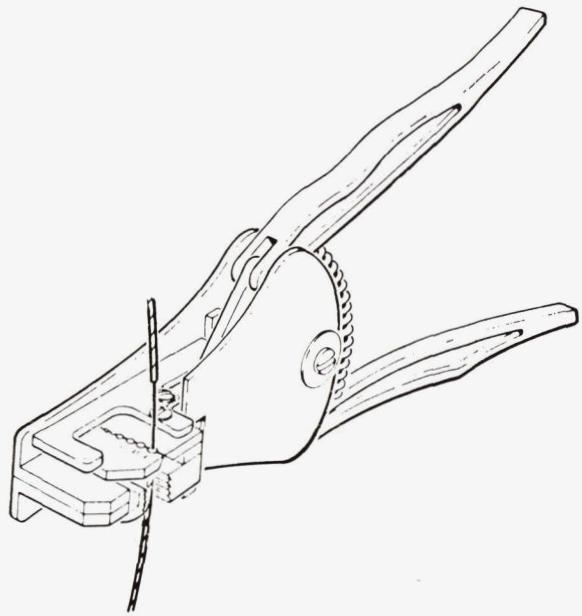


Figure 13-1. Typical Thermal Stripper

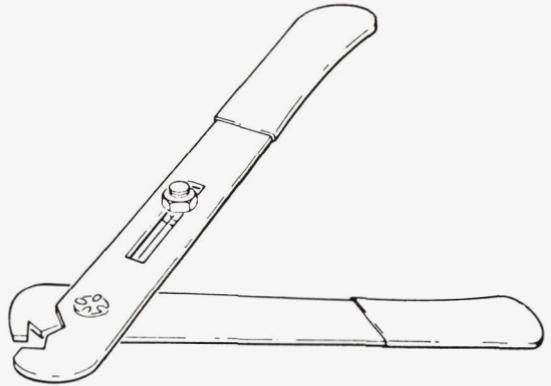
### 13.5.2 PRECISION CUTTING TYPES

Hand or machine precision cutting-type strippers shall be used to strip glass braid insulation and other insulation that cannot be removed by thermal strippers. (Refer to Figure 13-2.) Cutting-type strippers which permit operator adjustment shall not be used. Strippers shall be calibrated and checked for proper operation and shall be removed from work areas when found defective. Die openings for wire size other than the single size being used shall be masked off to prevent inadvertent use.

Razor blades, pocket knives, fingernail clippers, or similar nonapproved devices shall not be used to strip any insulation.



Proper Cutting-Type Stripper



Improper Cutting-Type Stripper

Figure 13-2. Typical Cutting-Type Strippers

### 13.6 SOLDERING AREAS AND TOOLS

#### 13.6.1 WORK AREA

The soldering area and work benches shall be maintained in a clean and orderly condition in accordance with NPC 200-4, Quality Requirements for Hand Soldering of Electrical Connections, and MSC-SPEC-C-5A, Specification for Apollo Spacecraft Cleanliness. All dirt, grease, oil, solder splatter, wire and insulation cuttings, and other foreign matter shall be promptly removed. Soldering areas shall be frequently and thoroughly cleaned. Smoking, drinking, or eating in the soldering areas shall not be permitted.

### 13.6.2 TOOLS

Tools detrimental to good practices shall not be used. Tools shall be returned to the tool crib at scheduled intervals for cleaning, servicing, inspection, and replacement.

#### 13.6.2.1 Bending Tools

Wire bending tools shall have smooth bending surfaces and shall be used to bend component leads without nicking, ringing, or otherwise damaging the lead or component.

#### 13.6.2.2 Soldering Irons

The size of soldering irons (tip size and shape, voltage and wattage rating) and the temperature shall be selected and controlled for optimum performance in relation to the work to be performed. Temperature control of the soldering iron may be accomplished through the use of a variable voltage supply, tip selection, or a combination of both. Transformer-type soldering guns shall not be used. Plated tips may be used provided the quality of the solder connection is maintained.

#### 13.6.2.3 Thermal Shunts

Thermal shunts, or heat sinks, shall be used as necessary to protect heat-sensitive components such as semiconductors, crystal devices, meter movements, insulating materials, etc., from damage due to heat while soldering. (Refer to Figure 13-3.) Thermal shunts shall be of such material, size, shape, and design so as to permit rapid application and removal with minimum interference to the soldering procedure and to provide rapid heat removal from the area being soldered. Thermal shunts shall be held in place by suitable means, such as friction or spring tension, which will prevent damage to the surface and insulation of the wire and to the component being soldered.

### 13.6.3 TOOLS AND MATERIALS FOR CLEANING

Tools and materials for cleaning component leads, soldered areas, and soldering iron tips and for removing gold plating shall be as specified below.

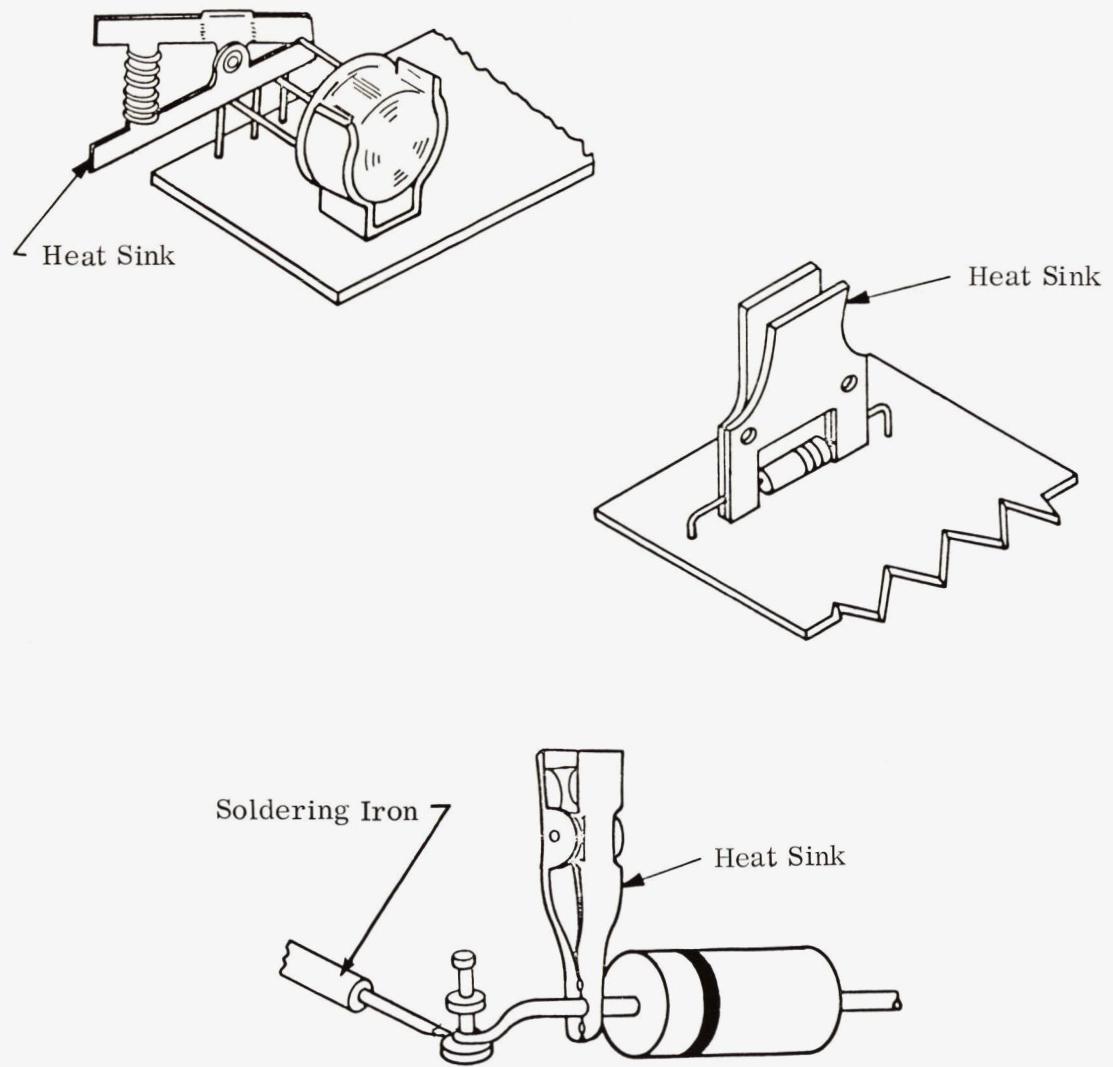


Figure 13-3. Proper Techniques for Soldering Component Leads Using a Heat Sink

### 13.6.3.1 Component Leads

Component leads shall be cleaned with an efficient cleaning tool. (Refer to Figure 13-4.) Knives, emery cloth, sandpaper, etc. shall not be used.

### 13.6.3.2 Soldered Areas

A medium-stiff natural or synthetic bristle brush or a lint-free industrial cleansing tissue that is dipped into an approved solvent (Refer to paragraph 13.6.3.6.) shall be used to remove flux following solder solidification. Wire brushes, knives, emery cloth, sandpaper, or other abrasives that produce a harsh abrasive action shall not be used.

### 13.6.3.3 Gold Plating

For removing gold plating from areas to be soldered, a white typewriter eraser conforming to Federal Specification SS-P-821, Grades 0-3/4, F or a suitable combination thereof, shall be used. An example of a pencil style eraser is shown in Figure 7-5.

### 13.6.3.4 Unheated Soldering Iron Tips

#### 13.6.3.4.1 Unplated Tips

Only flat, fine, single-cut, shear-tooth files shall be used for cleaning and dressing unplated copper tips that are cold.

#### 13.6.3.4.2 Plated Tips

Plated tips shall be cleaned with emery cloth or aluminum oxide cloth of approximately No. 320 grit size which will not remove the plating. Files shall not be used for cleaning plated tips.

### 13.6.3.5 Heated Soldering Iron Tips

A wet, fine-texture natural or synthetic sponge shall be used for cleaning heated unplated or plated soldering iron tips.

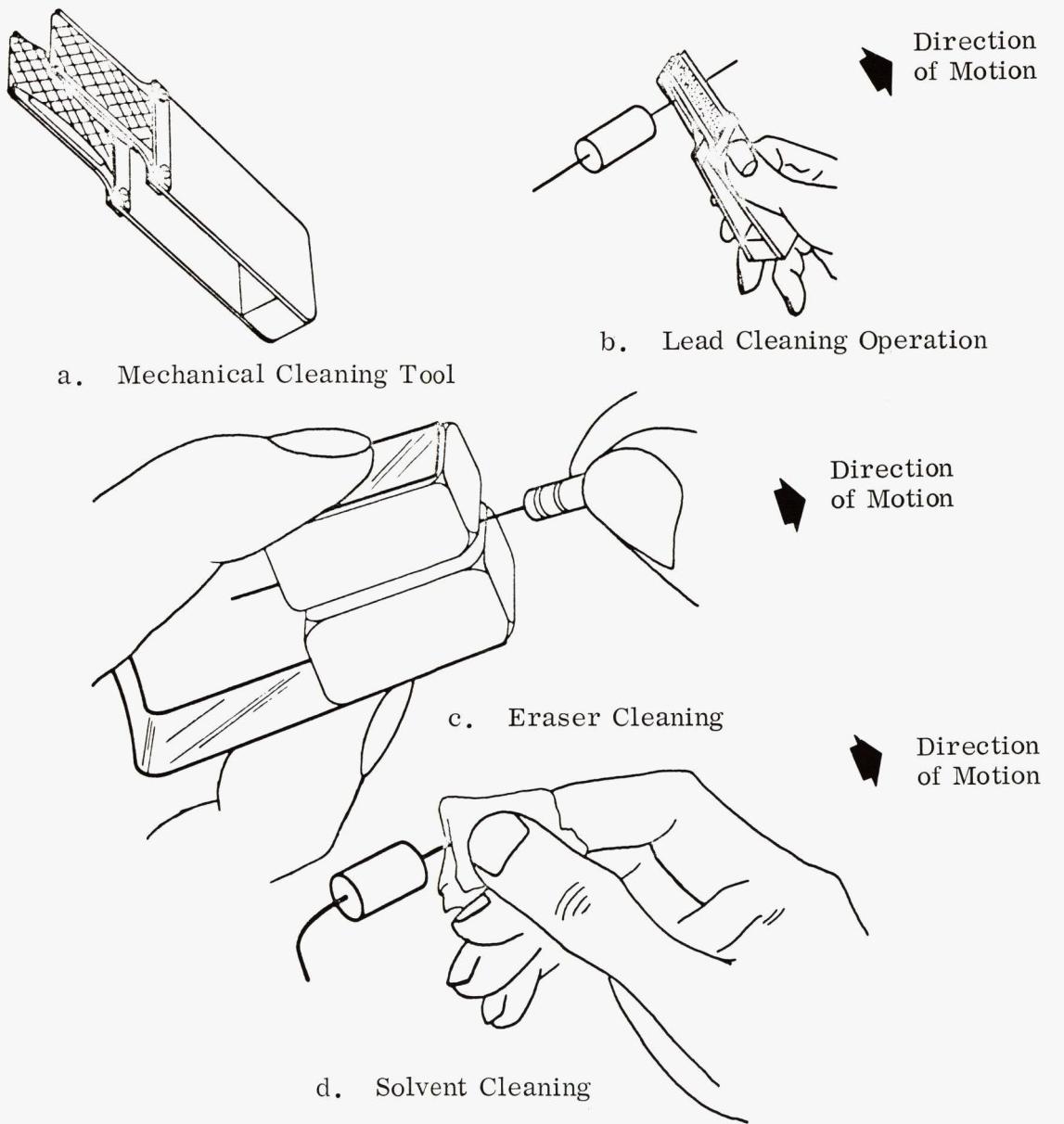


Figure 13-4. Component Preparation for Soldering

#### 13.6.3.6 Solvent

Ethyl alcohol, conforming to Federal Specification O-E-760, Grade I, Class A or Class B, or commercial grade 99 percent pure (by volume) isopropyl alcohol or other approved solvents shall be used for removal of flux, grease, or oil.

#### 13.6.3.7 Tool Cleanliness

Tool working surfaces shall be cleaned prior to use to remove all dirt, grease, flux, oil, and other foreign matter and shall be cleaned during use as is necessary.

#### 13.6.3.8 Gloves

Personnel who handle cleaned wires, leads, terminals, and printed circuit boards shall wear thin, lintless, clean, white approved gloves or finger tabs to prevent any contamination by contact with bare hands or fingers.

### 13.7 MECHANICAL LOADING DEVICES AND TORQUE WRENCHES

#### 13.7.1 INTEGRITY SEALS

Calibrated tools shall be sealed to insure against unauthorized alteration of calibration settings. A wire and lead-seal method shall be used if the tool has provisions for it; otherwise, the tool shall be sealed by a nonre-usable decal seal which will be visibly damaged if the calibrated setting is altered. Seals shall be placed on all external calibration adjustment points on the tools. Any broken seal shall be cause for rejection. (Refer to paragraph 13.2.)

#### 13.7.2 MARKING

Each tool shall be marked to identify it completely for the range or accuracy for which it is calibrated.

### 13.8 AUTOMATIC SOLDERING MACHINES

Machines used for the automatic soldering of electrical or electronic components shall be inspected to ensure they are maintained and operated in such a manner as to comply with NASA requirements for soldering electrical connections. Any such machine and its process shall be approved by NASA.

## SECTION 14

### IDENTIFICATION

#### **14.1 GENERAL**

This Section establishes inspection criteria for the identification of electrical and electronic components that are assembled during fabrication of spacecraft and spacecraft components. These items must have physical markings which enable ready recognition.

Applicable standards and specifications shall be used in identifying items in the fabrication of electrical or electronic components. The following paragraphs present the more prevalent and generalized applications of identification.

#### **14.2 PROPER IDENTIFICATION**

All wires, cables, and harnesses shall be identified according to the requirements of applicable process specifications. Inspection personnel shall ensure that the following provisions have been met:

- a. Wires and cables shall be identified and shall be traceable to the proper circuit function.
- b. Wires that have a common terminal connection or junction and with the same circuit functions shall have the same wire number, but shall have different segment letters.
- c. The connector designation shall be compatible with that of the corresponding mating equipment.
- d. Cables and harnesses that terminate with connectors shall have the proper P or J designation applied to the connectors. Figure 11-3 illustrates this type of identification.
- e. Terminal block junctions shall be properly identified.
- f. Wires that are installed to spare pins of connectors shall be identified by the pin designation and wire size.

#### 14.3 APPLICATION

Letters and numbers shall be imprinted on wires, cables, or sleeves using an approved method which does not impair the quality of the wire, cable, or harness. Identification shall be accomplished by the use of nonmetallic labels, sleeves, etc., on wires, cables, etc. (Refer to Figure 4-4 and Figure 4-8 for other identification methods.)

When a hot stamping process is used for wire identification, tests shall be conducted to ensure insulation integrity.

#### 14.4 LEGIBILITY

All identification characters shall be of sufficient size so that they are easily legible. The markings shall contrast with the surrounding surface and shall be permanent. Figure 14-1 shows a wire with inadequate identification. Figure 14-2 shows identification properly applied, but concealed by potting compound.

#### 14.5 LOCATION

Identification marks that are legible are of little value if these are hidden by another object, inaccessible behind panels, etc. The lack of the following shall be cause for rejection:

- a. Each wire shall be identified at not more than 5-foot intervals throughout its entire length.
- b. Wires, cables, and harnesses shall be identified within 6 inches of the end and each junction.
- c. Harness branches shall be identified within 6 inches of the parent trunk.
- d. Coaxial cables shall be identified within 3 inches of terminating ends and shall have the marking conform to that on the receptacle or other equipment. (Refer to Figure 11-3.)
- e. Identification shall be located within 6 inches of both sides of bulkheads or inaccessible areas through which wires, cables, or harnesses pass.
- f. Identification shall not be concealed by clamps, ties or sleeves, or other supporting devices. (Refer to Figures 14-3 and 14-4.)



Figure 14-1. Example of wire with inadequate identification.

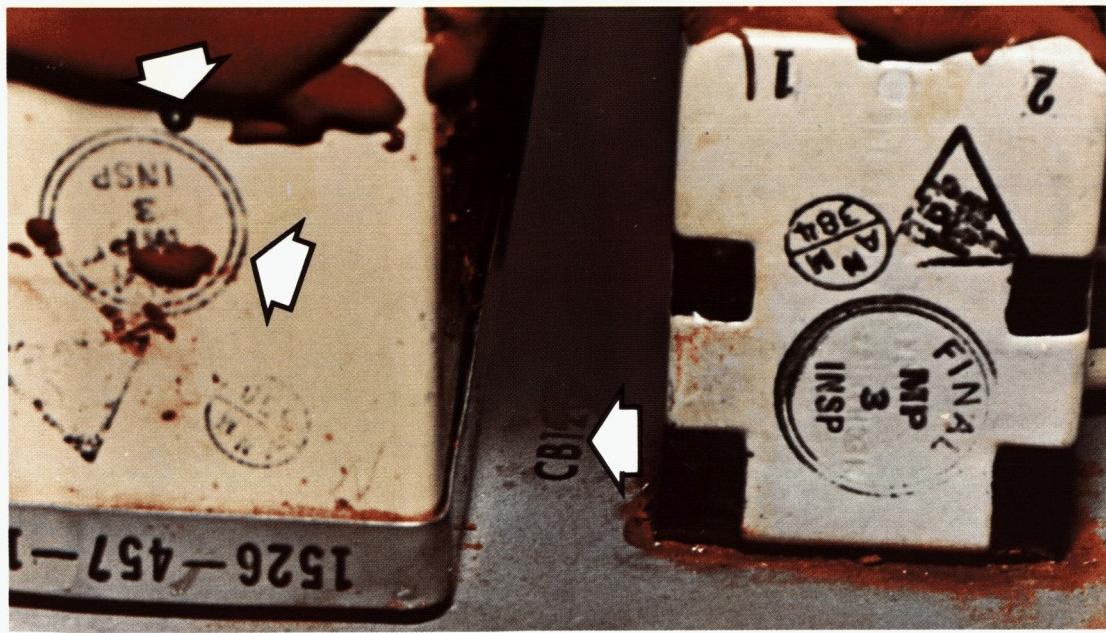


Figure 14-2. Identification has been properly affixed, but it is obliterated by potting compound.

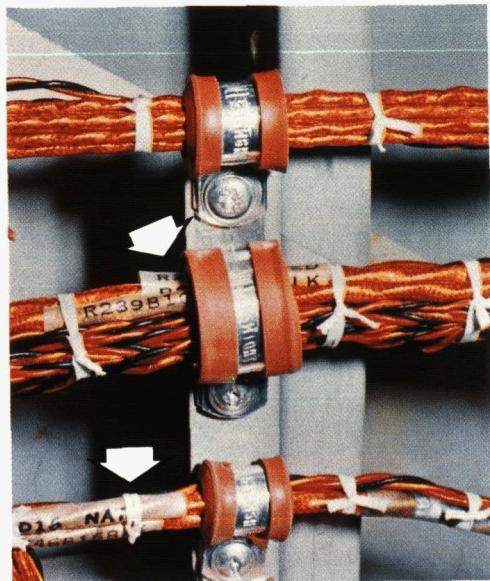


Figure 14-3. The identification marks on the sleeves are hidden because the sleeves are located under clamps or under spot ties.

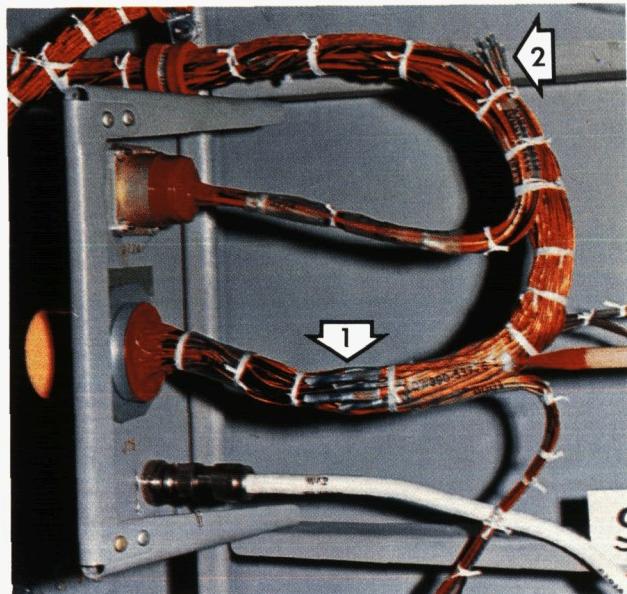


Figure 14-4. The identification marks on the wire bundles are clearly visible and match those of the mating connectors. (The splices (1) have not been staggered nor have the end caps (2) been staggered or identified.)

## SECTION 15

### CLEANLINESS

#### 15.1 GENERAL

This Section provides the requirements and inspection criteria for cleanliness for spacecraft electrical wiring, electrical assemblies, and subassemblies during fabrication, after installation, and during and after field repair. These criteria and standards are supplemental to the following documents referenced in paragraph 1.3.2:

- a. MSC-ASPO-S-6A, MSC Supplement to NPC 200-4—June 1, 1966.
- b. MSC-STD-C-4, Clean Rooms and Work Stations.
- c. MSC-SPEC-C-5A, Specification for Apollo Spacecraft Cleanliness.
- d. MSC-SPEC-C-8, Apollo On-board Equipment Cleanliness.
- e. FED-STD-209, Clean Room and Work Station Requirements, Controlled Environment.

#### 15.2 ACCEPTABLE PRACTICES AND EQUIPMENT

Completed and installed electrical systems and subassemblies shall be visibly clean at all times. Visibly clean means the absence of all foreign and harmful particulate and nonparticulate matter visible to the normal unaided eye (corrected vision accepted). Particulate is identified as matter of miniature size with observable length, width, and thickness as contrasted to nonparticulate (film) matter without definite dimension.

Inspection conditions shall be those normally encountered in spacecraft inspections. Magnification devices shall not be used; however, reflecting devices (dental mirrors, borescopes, etc.) are permitted. Lighting shall be supplemented as necessary to provide the appropriate illumination for inspection.

Surfaces of electrical equipment that are exposed to the crew-bay environment shall be cleaned to a visibly clean condition (including the absence of visible hydrocarbons). This cleaning shall be accomplished in a clean room or at a clean room

station of class 100,000 or better as defined in MSC-STD-C-4, Clean Rooms and Work Stations and as required by MSC-SPEC-C-8, Apollo On-board Equipment Cleanliness.

### 15.3 CAUSES FOR REJECTION

The following listed items are indicative of the more common contamination encountered in the fabrication of electrical wiring assemblies. The presence of these items shall be cause for rejection and/or rework. Figures 15-1 through 15-4 show various conditions of contamination.

#### 15.3.1 FABRICATION CONTAMINATION

- a. Corrosion products.
- b. Solder splatter (Refer to Figure 15-1).
- c. Wire strands/insulation.
- d. Coating, potting materials.
- e. Wire clippings and other material scraps.
- f. Lubricants and other film materials.
- g. Harmful surface oxides.
- h. Residues/reaction products from cleaning agents, coolants, or lubricants.
- i. Fluxes and/or other preparation agents.

#### 15.3.2 INSTALLATION/CHECKOUT CONTAMINATION

- a. Tie cord pieces (remnants).
- b. Insulation, wire strands and braid, or safety wire.
- c. Pieces of cable brackets and clamps or other objects.
- d. Thread material (metals), drill chips, filings, and metallic particles.
- e. Pieces of grommets (Nylon, rubber, etc.).
- f. Films and smudges.
- g. Coating and potting material.

#### 15.3.3 PERSONNEL CONTAMINATION

- a. Scale.
- b. Hair.



Figure 15-1. Contamination—Solder Splatter

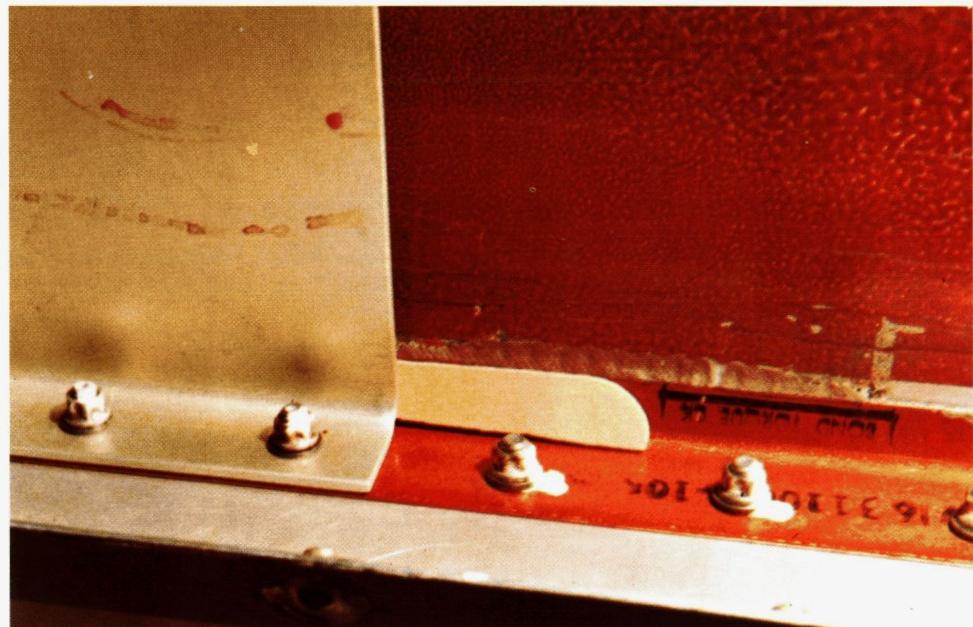


Figure 15-2. Contamination—Wooden Spatula



Figure 15-3. Contamination—Dirt, Debris, and Loose Hardware



Figure 15-4. Contamination—Potting and Sleeving

- c. Lint.
- d. Fibers.
- e. Cosmetics.
- f. Fingerprints.

#### 15.3.4 HANDLING AND PACKAGING CONTAMINATION

- a. Finger smudges.
- b. Dirt, dust, etc.
- c. Particulate contamination from packaging materials.
- d. Particulate contamination from dessicant, cushioning materials, preservatives, and wrapping.

#### 15.4 BLACK LIGHT USAGE

In addition to visual inspection, assemblies shall be inspected by ultraviolet light (black light), and any evidence of hydrocarbon contamination shall be cause for rejection. Ultraviolet light inspection will not detect common hydrocarbon fuels, some silicone greases, thread sealants, and fluorocarbon greases commonly found as contaminants. Ultraviolet light will cause the following commonly used materials to fluoresce: most water-soluble machining and cutting oils, some lints, molybdenum disulfide, lubricating oil (MIL-O-6086, Lubricating Oil, Gear, Petroleum Base), grease (MIL-G-4343, Grease, Pneumatic Systems), silicates from cleaning solutions, and some inorganic compounds found in fluorescent penetrant inspection dyes.

#### 15.5 CORRECTION OF DISCREPANCIES

When any of the above or similar discrepancies are found, immediate appropriate remedial action such as cleaning, vacuuming, etc., shall be implemented (and the item shall be re-inspected) to preclude additional damage. Discrepancies shall be investigated to prevent recurrence on subsequent equipment.

#### 15.6 ENVIRONMENTAL REQUIREMENTS

The minimum environmental conditions for fabrication, spacecraft crew compartment operations, and for processing of equipments (such as experimental) which are to be employed in the crew compartment of the spacecraft are shown below.

### **15.6.1 DURING FABRICATION**

Electrical wiring assemblies and subassemblies shall be fabricated under conditions commensurate with the quality required of the end product. Generally, all soldering, electrical fabrication, and assembly shall be performed in an environmentally controlled room as follows: (Reference, MSC-ASPO-S-6A)

- a. Temperature:  $75^{\circ} \pm 10$  F.
- b. Relative Humidity: 65 percent maximum (at room temperature).
- c. Air Flow: Inflow of additional air to the room should be controlled and should utilize a filter system capable of protection against the infiltration of dust.

### **15.6.2 DURING CREW COMPARTMENT PREPARATIONS**

During normal work activity and/or while hatches are open, the crew compartment shall be provided with conditioned, filtered air. Input air to the compartment shall meet the following requirements: (Reference, MSC-SPEC-C-5A)

- a. Hydrocarbons: Not to exceed 45 ppm\* (pentane equivalent).
- b. Temperature:  $70^{\circ} {}^{+5}_{-0}$  F.
- c. Relative Humidity: Not to exceed 50 percent (or less if necessary to preclude condensation on cabin interior).
- d. Airborne Particulate Level: Class 100,000 or better (in accordance with FED-STD-209).
- e. Continuous monitoring of crew compartment environmental conditions generally is not required; however, a regularly scheduled filter replacement and a daily monitoring of input conditions shall be implemented to ensure that the above requirements are met or exceeded.

### **15.7 FIELD REPAIR CONTAMINATION**

All electrical wiring operations to be performed in the field shall ensure that contamination by the outside elements shall not impair the integrity of the work. Following completion of the repair, the wiring shall be cleaned and inspected.

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\*Parts per million